

G7 Broadband Dynamics



How Policy Affects Broadband Quality in Powerhouse Nations

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A M E R I C A N E N T E R P R I S E I N S T I T U T E

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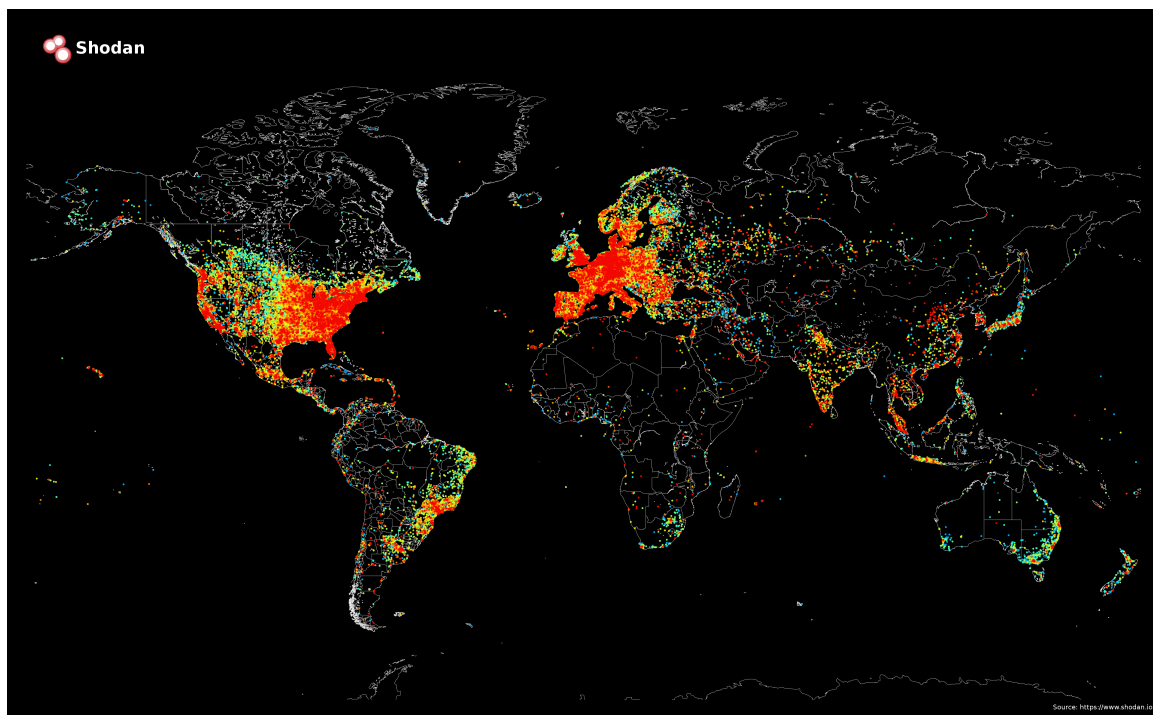
Executive Summary

As we become more dependent on information technologies, questions about how to build, sell, regulate, and upgrade broadband networks become increasingly crucial. Broadband networks are key enablers of information technologies as well as products of them, so their status tells us a great deal about the extent to which technology permeates the modern society.

Policy experiments over the past decade provide insight into the effects that regulatory policies have on the vibrancy of these networks and the richness of the applications they enable. Policy is not the whole story, however: nations differ with respect to geographic, historical, and cultural factors that strongly influence the motivation to invest in technology and the ability to reap its benefits.

Isolating the effects of policy from these other factors is easiest when we compare broadband diffusion, quality, utilization and cost in nations that are similar in size, economic development, education, and population distribution; hence, this study examines broadband in the Group of 7 (G7) nations.

The Internet Heat Map developed by Shodan also tells us that the G7 is where the action is on the global Internet.



Internet Heat Map

Source: Shodan (<https://www.shodan.io>).

Three Broadband Policy Models

Three regulatory models emerge from this analysis:

- The Pioneer Model of dynamic, facilities-based competition in the United States and Canada;

- The Contingent Model of semi-deregulated advanced networks and price-controlled legacy networks in Japan, the United Kingdom and Germany;
- The Utility Model of low-priced, poor-quality, subsidy-dependent service over stagnant broadband infrastructure in France and Italy.

Even within the G7, there are sharp differences in the starting points for the broadband race.

Some countries had extensive cable TV networks before broadband was invented, others had cable only in cities, and yet others had no more than a smattering anywhere. The extent of cable

coverage influenced the development of regulatory models that in turn either advanced or suppressed the deployment of broadband networks.

The recognition of the dynamic nature of technology is challenging to historical norms in public infrastructure policy.

In some countries, broadband was addressed as utility networks had been in the past, as a one-time build that would essentially have a permanent life span, while others adopted policies that encouraged the displacement of first-generation broadband networks by better ones in the

second, third, and fourth generations. The recognition of the dynamic nature of technology is challenging to historical norms in public infrastructure policy. The Pioneer Model best accommodates dynamism, but the Contingent Model can do a credible job when regulators are highly skillful, as they are in the UK; it is much less effective in Germany and only moderately effective in Japan.

Three Phases of Broadband Development

Broadband networks appear to develop across three distinct phases:

- A Basic Broadband stage in which existing wired telephone, cellular telephone, and cable TV networks are coupled with broadband electronics to provide a basic level of connectivity 10 to 100 times greater than the legacy system.
- An Advanced Broadband stage in which the wire and radio infrastructure is reconfigured to work better for broadband and connectivity improves another 10 to 100 times.
- A Pervasive Broadband stage in which most end-user connections are wireless at speeds produced only by wired systems in earlier stages and a pervasive fiber optic backbone extends so thoroughly that wireless can be provided over short hops that are not technically challenging.

It was not possible to jump directly from the prebroadband status quo to the Pervasive Broadband stage because key technologies did not exist; indeed, the technology that will carry us into the pervasive stage is still not complete. Hence, broadband poses a massive challenge to policymakers simply by virtue of its dynamism.

Universal Service

Universal coverage for Basic Broadband is a solved problem in the G7 because the combination of DSL, cable, 3G and 4G mobile, fiber, and satellite reaches even the most remote parts of these nations. The pressing issues today concern the initial deployment of advanced and pervasive technologies and their diffusion from healthy urban markets to more challenging rural ones.

The use of subsidies is a live issue in rural diffusion: should subsidies be used to stimulate research and development, as they are in the form of National Science Foundation grants to US universities? Or should they fund initial deployment, as they are in the Contingent Model nations? Should they be used to improve rural coverage and quality, as they are in most nations?

Or should subsidies be used to create competitors, as they often are in Utility Model nations? Shall we simply use subsidies to create the illusion of low consumer prices by shifting costs? Free Mobile, the low-price leader in French mobile services, is a regulatory creation that depends on inflated telephone termination fees for its survival, for instance, and many self-styled public interest groups place an inordinate emphasis on low prices at the expense of technical progress.

Measuring Performance

Policy analysts often measure broadband progress by metrics that tell very little about where we are on the expected trajectory, such as “penetration” (subscriber count) and dollars per bit per second of capacity. It is better to examine the deployment of advanced technology networks, the

Web servers and browsers are the limiting factors in web surfing speed today, not networks.

actual performance networks exhibit while running real-world applications, and the volume of data they carry. When we do this, we see the most advanced wired and mobile networks are those in Japan, the US, and Canada; networks in the US and Canada carry the heaviest data loads; the heaviest mobile loads are carried in Japan and the US; and smartphone adoption is most pervasive in the US and UK.

The emphasis on raw network capacity has caused policymakers to overlook the fact that the personal experience of the World Wide Web is shaped more by the performance of servers, personal devices, and browsers than by network capacity; the FCC’s data shows that 60 percent of the load time of web pages is determined by nonnetwork factors as long as consumers are connected at 20 Mbps or better. Comparison of the Akamai measurements of peak network capacity and web page load time suggests that nonnetwork factors may contribute five to 15 times as much web page delay as average networks across the G7. The FCC acknowledges that consumers see little benefit in web page load time from upgrading to networks faster than 10 Mbps. The claim that arbitrary increases in last mile capacity from the current norm to 1 Gbps will produce “blazingly fast web surfing” is simply false. Faster networks can produce benefits, but a better web experience is not prominent among them.

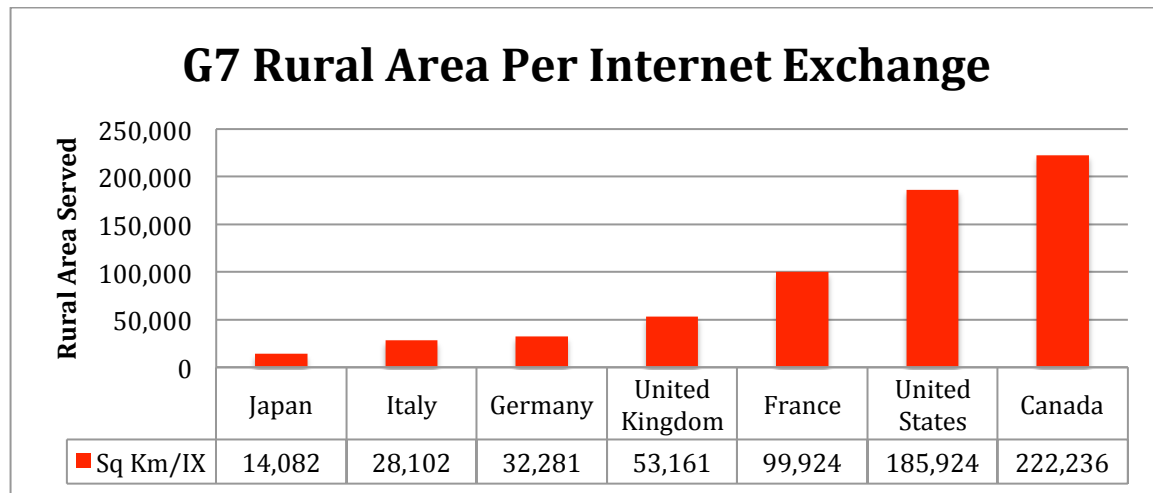
The Broadband Scorecard

Summing up all the factors and placing them in a scorecard makes the analysis easy to comprehend. In terms of eight criteria comprising geography, deployment, adoption, and usage, G7 nations following the Pioneer Model do best, Utility Model nations do worst, and Contingent Model states are in the middle.

	Rural	NGA	LTE	Smart phone	>10M	Mobile >4M	Mobile Usage	Mobile Usage	Score
United States	1	2	1	1	2	2	1	2	1.50
Canada	1	2	1	2	2	1	1	2	1.50
Japan	3	1	2	2	1	1	2	1	1.63
United Kingdom	2	2	3	1	2	1	2	2	1.88
Germany	2	2	2	2	3	3	3	3	2.50
France	2	3	3	2	3	1	3	3	2.50
Italy	3	3	3	3	3	1	3	3	2.75

G7 Broadband Scorecard
Source: See Figure 72.

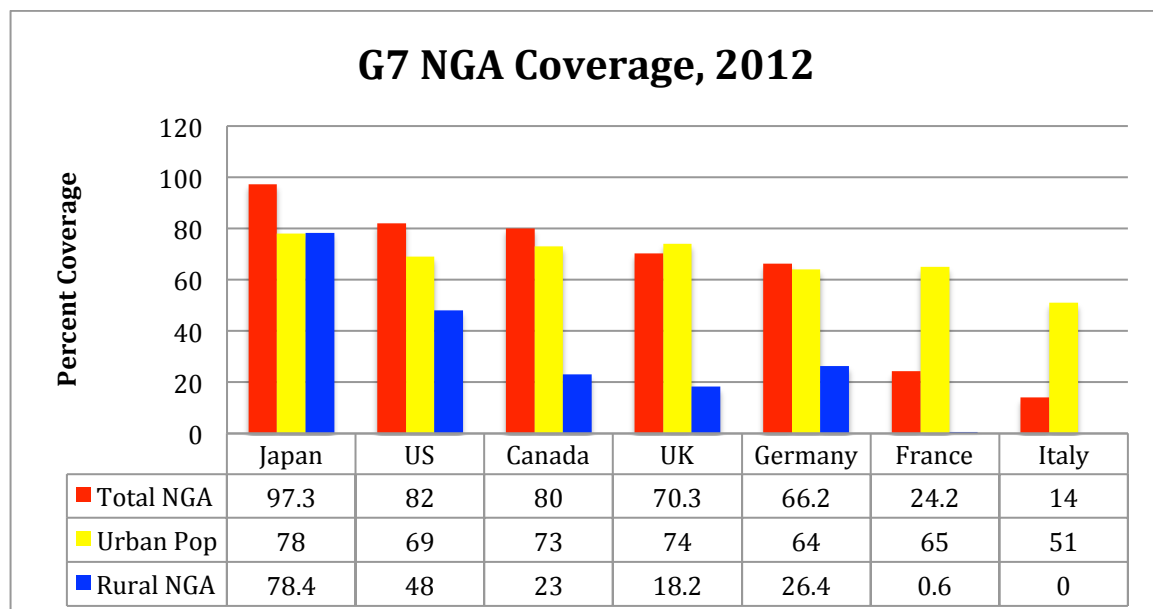
The first factor is rural population diffusion, an obstacle that has to be overcome. The next graph is a rough calculation of the square kilometers of inhabited land area served by each Internet Exchange. This tells us how many kilometers of cable must be installed to connect people to the Internet in a relative sense. The US and Canada have the hardest problem to solve.



G7 Rural Area per Internet Exchange

Source: See Figure 6.

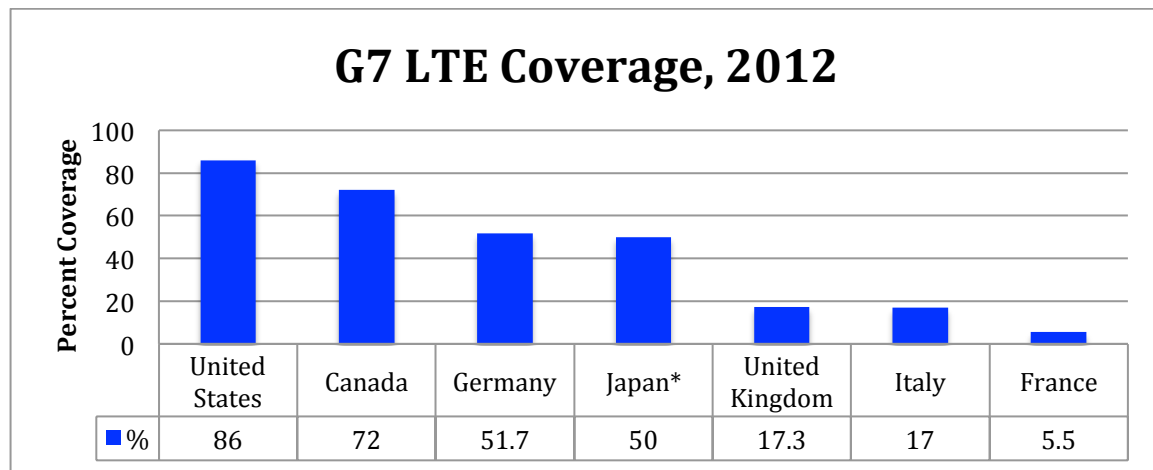
The next factor is the diffusion of advanced broadband networks in each country, or next-generation access (NGA) in policy speak. Networks that can provide 25 Mbps of capacity without significant congestion generally qualify as NGA. The most important dimension in this graph is “Total NGA,” the red bar. Japan does exceptionally well here, and the US and Canada outperform Europe.



G7 NGA Coverage, 2012

Source: See Figure 17.

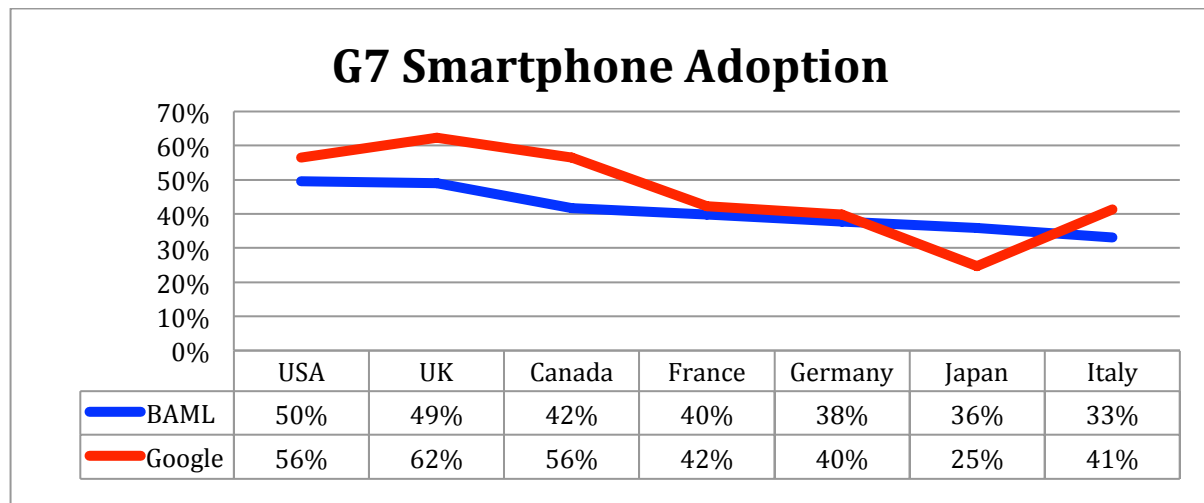
Moving on from wired networks, LTE and LTE Advanced provide advanced mobile networking, technologies that are best developed in the US and Canada.



G7 LTE Coverage, 2012

Source: See Figure 22.

Europe is finally rolling out LTE, just as the US and Canada are upgrading to the next generation, LTE Advanced. Using LTE to its peak capability requires smartphones, and we can see that their adoption is not uniform across the G7. The US and UK are numbers one and two on this factor, with their respective positions dependent on which database we use, Google's or the Bank of America/Merrill Lynch Global Wireless Matrix.

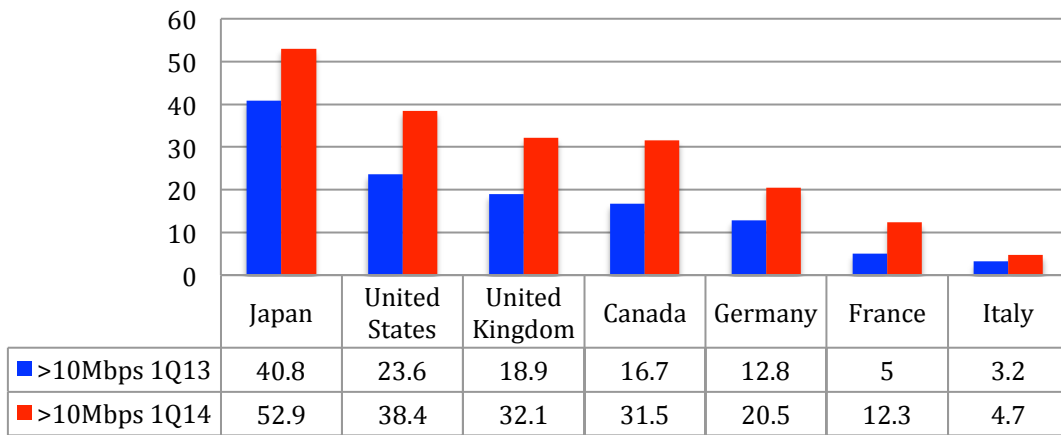


G7 Smartphone Adoption

Source: See Figure 28.

One of the most meaningful measurements of network technology diffusion is the percentage of connections at the highest speed tier. On wired networks, Japan and the US do best here; because of the way this is measured, a network needs to have raw capacity of more than 30 Mbps for connections to exceed average performance of 10 Mbps.

G7 Percent Connections >10 Mbps, 2013–14

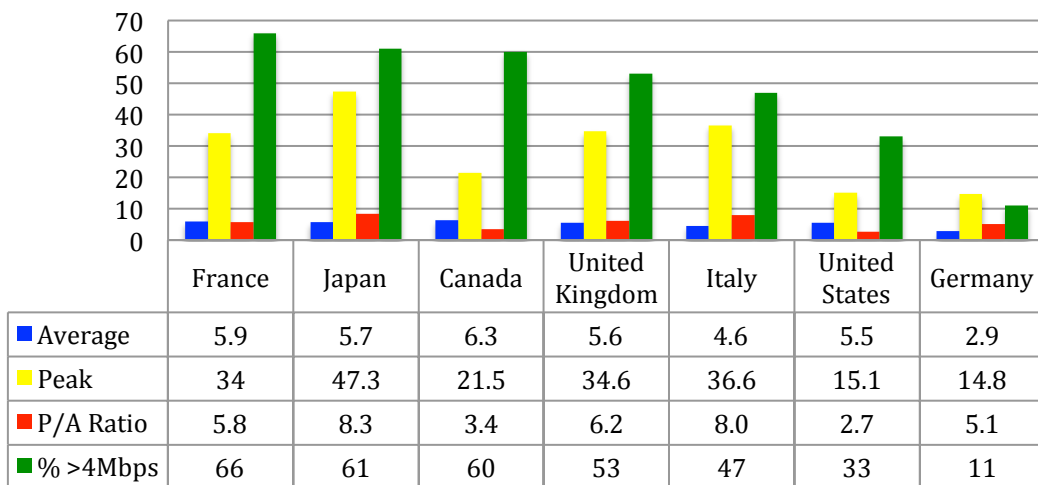


G7 Wired High-Speed Broadband Adoption

Source: See Figure 38.

Wired networks are fine, but mobile is becoming the first screen for most in the developed world and, in fact, the only screen for many. The green bar in this graph tells us how common 4 Mbps connections are on mobile networks. In this dimension, France, Japan, and Canada are the leaders. In France, mobile networks are as fast as wired ones in some measurements; this reflects the poor quality of France's wired infrastructure.

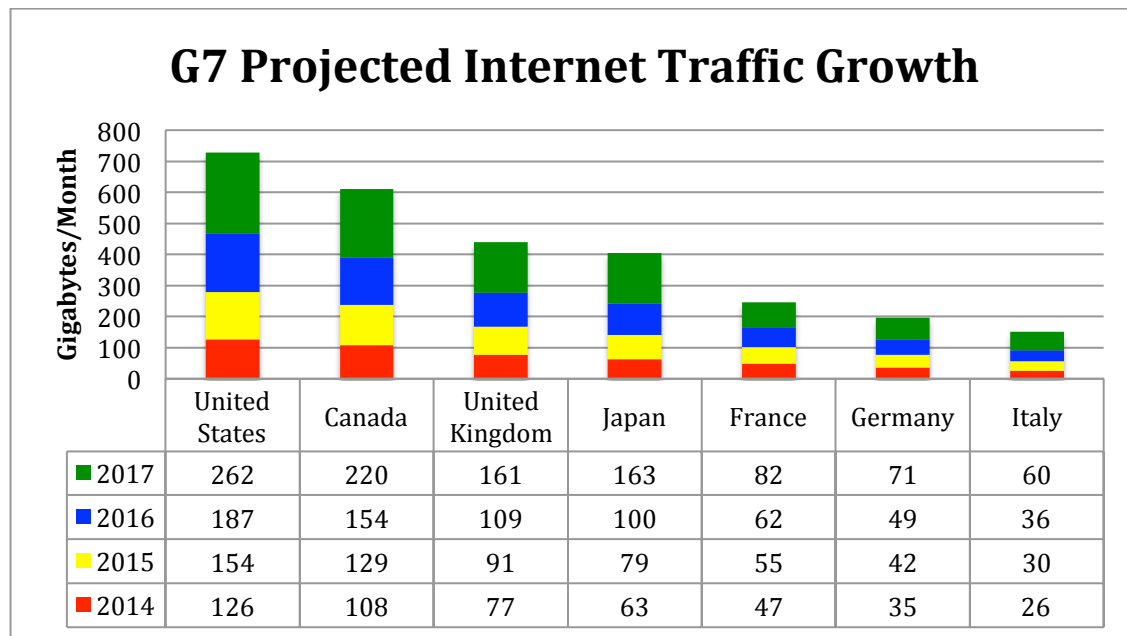
G7 Mobile Broadband Speed Q1 2014



G7 Mobile Broadband Speed Q1 2014

Source: See Figure 42.

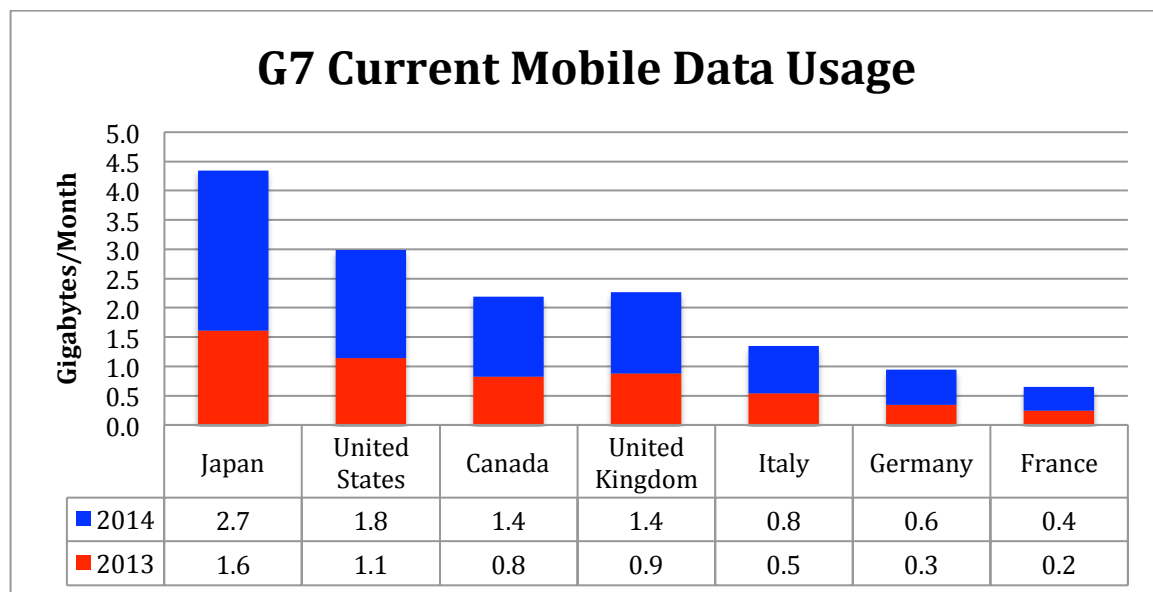
Good networks are nice to have, but nobody gets much benefit from them if they are not heavily used. In terms of wired network usage, the US is far and away the leader in the G7.



Projected Internet Traffic

Source: See Figure 61.

The pattern is similar for mobile usage, except Japan sneaks into the lead from fourth place in wired. This is odd because Japan is not a big smartphone nation; it suggests that people are using mobile networks from tablets and laptops in Japan as well as from smartphones. Indeed, there is some evidence that East Asian nations exhibit a new kind of “cord-cutting” where high speed broadband comes exclusively by wireless for many affluent young people.



G7 Current Mobile Data Usage

Source: See Figure 62.

This formulation does not tell the whole story, but at least it isolates most policy factors from nonpolicy factors. The data tell the story rather better than anecdotes do.

We can almost predict the standings on this scorecard from the state of cable TV in 1999; with the exception of Italy, the order is preserved. This does not signify that cable is the end-all and be-all of broadband; that is the status of LTE Advanced and fiber optic networks. Rather, the presence of an alternative network governed by a private carriage (rather than common carriage) regulatory framework allowed the US and Canada to devise regulatory models that emphasized

The study finds that the key policy variable is the ability of service providers to respond to user demand.

competition, innovation, risk capital and ingenuity above blind obedience to national plans and outdated regulatory dogma.

The study finds that the key policy variable is the ability of service providers to respond to user demand. In nations that allow vertical integration of cables, switches, routing, and interconnection, carriers are able to increase capacity at the times and places that best meet demand, and to shift from

wired to wireless modalities and from lower-capacity to higher-capacity technologies as appropriate. Nations that disallow vertical integration discourage timely upgrades and complicate them by introducing coordination issues that are not easily addressed.

The menu of choices for policymakers is relatively simple: if we want a dynamic broadband marketplace in which citizens enjoy high-performance networks at reasonable prices, it is necessary for regulators to be humble enough to allow the competitive dynamic to unshackle human ingenuity. If we are content to follow the leader and move more slowly, we can adopt the Contingent Model with a micromanaging regulator, but who will be the leader if we do? If we want stagnation, we can follow the Franco-Italian “almighty regulator” approach and bemoan our lack of progress.

The data point unambiguously to the proper path: the geography that US broadband networks have to cover is too challenging for any but the most efficient and effective regulatory model.

Overview

This study evaluates the quality of America's broadband network infrastructure against relevant international competitors to determine how well the various regulatory models are working. It judges policy success according to the buildout and utilization of advanced networks of sufficient quality to enable consumers to use state-of-the-art applications and to enjoy extensive access to content.

In addition to these primary factors, the study examines several secondary indicators, such as population distribution, smartphone adoption, next-generation access (NGA) deployment, competition, rural coverage, fiber deployment, gigabit networks, adoption growth, technology use by age group, download times, network capacity, LTE coverage, web page load times, the SamKnows Promise Index, projected traffic growth, pricing, perceived value, and policy model details.

Why the G7?

This study compares the condition of America's broadband ecosystem against the other members of the Group of 7 (G7—Canada, France, Germany, Italy, Japan, and the United Kingdom) for two reasons: because G7 nations are the most comparable to one another and because the G7 is where the action is. The Internet Heat Map shows the greatest concentration of Internet-connected devices is in the G7.

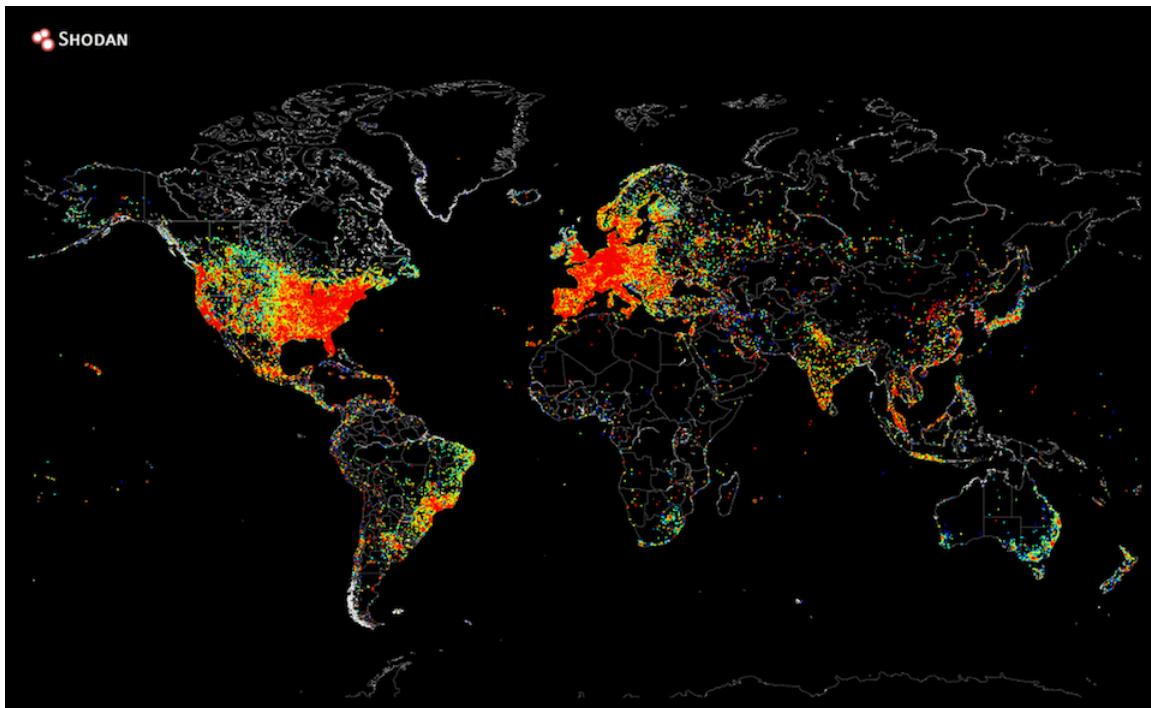


Figure 1. Internet Heat Map

Source: Shodan (<https://www.shodan.io>).

The goal of the study is to determine whether America's broadband policies are producing the desired results to a greater or lesser degree than those employed by comparable nations.

The study examines the effects of the three policy models used within the G7:

1. The Pioneer Model used by the US and Canada.
2. The Contingent Model used in Japan, Germany, and the UK.
3. The Utility Model used in France and Italy.

The study finds that disparities in broadband performance and quality cannot be accounted for strictly on the basis of policy, for three reasons:

1. Each nation entered the broadband era with a different level of inherited infrastructure, some of which was more suitable for broadband deployment than the rest.
2. Each nation has different cost factors irrespective of inherited infrastructure, such as population distribution (the concentration of population into extremely high-density or low-density areas) and distance from key Internet Exchange Points (IXP).
3. Interest in and preparation for use of the Internet depends on demographic factors such as the education, income, and age of the population; English language skills; and attitudes toward technology. These vary considerably across nations.

The study finds that the key policy variable is service providers' ability to respond to user demand.¹ In nations that allow vertical integration of cables, switches, routing, and interconnection, carriers are able to increase capacity at the times and places that best meet demand and to shift from wired to wireless modalities and from lower-capacity to higher-capacity technologies as appropriate. Nations that disallow vertical integration discourage timely upgrades and complicate them by introducing coordination issues that are not easily addressed.

Broadband's Economic Role

Broadband networks are parts of a market for information services and content. Networks serve as platforms for end-user services in areas such as personal communication, publishing, entertainment, education, and health care. Networks are not ends in themselves but platforms in a rich ecosystem of innovation that enables economic growth, personal fulfillment, high quality of life, and a host of other benefits.

Networks must be powerful and capable enough to enable applications; to the extent that applications are hobbled by or forced to adapt to network conditions, networks are problematic. To the extent that innovators and users are able to create and enjoy valuable applications, networks are successful.

A number of attempts have been made to quantify the effects that broadband quality has on economic growth and development, but none of them is completely satisfying.² Broadband networks are parts of a broad market for information and communication technology (ICT) services, not the entire market. As the International Telecommunication Union (ITU) study *Impact of Broadband on the Economy* points out, broadband interacts with the economy in several ways: it requires critical mass, is most effective at lowering transaction costs, produces fastest results in large firms, and is primarily valuable when it stimulates new applications. Its impact is neither instant nor automatic.³

The need to formulate innovation-friendly policies to enhance the power of networking to develop economies is documented in a number of long-running, reputable studies by organizations such as the *Economist's* Economic Intelligence Unit, INSEAD, and the World Economic Forum, ranking nations on their use of ICTs to create jobs and stimulate economic growth.

Each of these studies assigns a relatively small fraction of ICT readiness to broadband network quality and price: typically, 20 percent or less.⁴ INSEAD, for example, lumps network factors

such as capacity, price, and international bandwidth into a category that includes content accessibility, electricity, and digital literacy; altogether, these factors account for one-quarter of the total index.⁵

It is therefore prudent to understand that the overall market for ICT services is a diverse blend of factors that includes demand, investment, utilization, tax policy, regulatory inclination, and applications. It is therefore misleading to simply rank nations on broadband speed; it is quite evident that diffusion of competent networks and broad adoption of networks are much more important to society and the economy than a few people enjoying the most technically advanced connections.

Neighborhood network capacity is balanced with capacity in other parts of the Internet.

In any case, economic analysis of the connection between broadband capacity and gross domestic product (GDP) is outside the scope of this study, which focuses on the impact of regulation on the dynamism of broadband markets.

Broadband Technologies

Although “fast” networks (those with high capacity and low delay) are generally preferable to slow ones, broadband capacity has a point of diminishing returns. This becomes evident in examining the current mania for ultra-high-capacity “gigabit” networks (those with capacities of 1,000 megabits per second or more). Most of world’s broadband residential networks in urban and suburban areas have peak capacities of 10–100 Mbps today, and the common use of gigabit networks is for aggregating end-user links rather than serving as an end-user link in its own right. Widely used broadband technologies (most of which were invented and developed in the US) include

- Hybrid twisted-pair copper/fiber networks (using VDSL2+ and copper loop lengths of 3,000 feet or less) that provide each customer with 40–50 Mbps of unshared capacity over bonded pairs or half as much over single pairs.
- Hybrid coaxial copper cable/fiber networks using DOCSIS 3.0 that provide 160 Mbps of shared capacity and 20–100 Mbps to each connection.
- LTE and LTE Advanced mobile networks providing 10–100 Mbps of capacity to each user.
- Optical Ethernet, a fiber- and switch-based aggregation technology running at speeds from 100 Mbps to 400 Gbps.
- Passive Optical Networking (xPON), a passive fiber optic residential technology typically providing connection capacity of 20–1,000 Mbps.

These technologies were primarily invented in the US. Gigabit networks use xPON and fiber optic Ethernet today and may be provided over copper/fiber hybrids in the near future.

Neighborhood network capacity is balanced with capacity in other parts of the Internet. High last-mile capacity is wonderful, but so are content delivery networks (CDNs), local caches, image-reformatting services, increased middle-mile capacity, and better connections to IXPs.

To the extent that service providers overinvest in last-mile capacity, they may underinvest in capacity improvements in other parts of their networks. If each residence has a 1 Gbps connection but the common Internet Exchange port remains at 10 Gbps (the current norm), gigabit customers will not achieve increased performance across the expanse of the entire Internet. Studies of web page loading times on today’s Internet suggest that today’s common networks already outperform today’s common web servers; at connection speeds of 25 Mbps, server and browser limitations, rather than network factors, cause 60 percent of the web page load time users experience.⁶

There is good reason to believe that both Korea and Japan have overprovisioned residential capacities and underprovisioned internetwork capacities, but the data on this subject are somewhat sparse and ambiguous; one telling example is Net Index by Ookla (a compilation of Ookla Speedtest scores), a crowdsourced broadband capacity measurement that ranks Japan fifth in the G7 in terms of download speed despite the ubiquitous deployment of 100 Mbps Fiber-to-the-Home or -Basement (FTTH/B) services in that country.⁷ Crowdsourced measurements are unreliable, so this conclusion is dubious.

Starting Points

Nations did not enter the broadband era on equal footing. Some countries—the US, Canada, Belgium, and the Netherlands, in particular—had widely deployed cable TV networks in the late 1990s, but most did not.⁸ The former Soviet satellites not only did not have cable TV, but their telephone networks were sparsely deployed and of poor quality; the USSR did not place a high premium on free speech and entertainment.

Nations with low-density housing norms, such the US, tended to have longer copper wire lengths than high-density nations, and distance is the enemy of network capacity. Fortunately, fiber and coaxial cable overcome many of the effects of a dispersed population, and nations with low density had more reason to install coaxial cable for television viewing than those with higher urban concentration.

The widespread existence of coaxial cable impedes fiber deployment because coaxial is capable of achieving very high speeds. The modern digital cable system already transmits three to six gigabits of digital TV information each second and can offer gigabit speed for Internet access by reassigning channel capacity from TV to broadband.

Population Distribution. Costs of broadband and upgrade progress rates are largely a function of bandwidth and distance, where rural regions and heavy users are more expensive to serve. Rural costs are high because of cabling and switching costs and the difficulty in sharing facilities such as wire and switches. High-volume users require additional aggregation capacity, and even super-dense cities can be problematic because of overcrowding in shared ducts and conduits. The addition of dedicated telephone lines to support fax machines in the 1980s and modems in the 1990s jammed conduits in New York and similar cities. Switching from copper to fiber alleviates conduit overcrowding.

The distribution (rather than the average density) of the US population at the start of the broadband era raised difficulties for broadband deployment and upgrades. Compared to other G7 nations, the US has the second-highest concentration of population in the 10 percent of most populated regions and the second-lowest rural density.

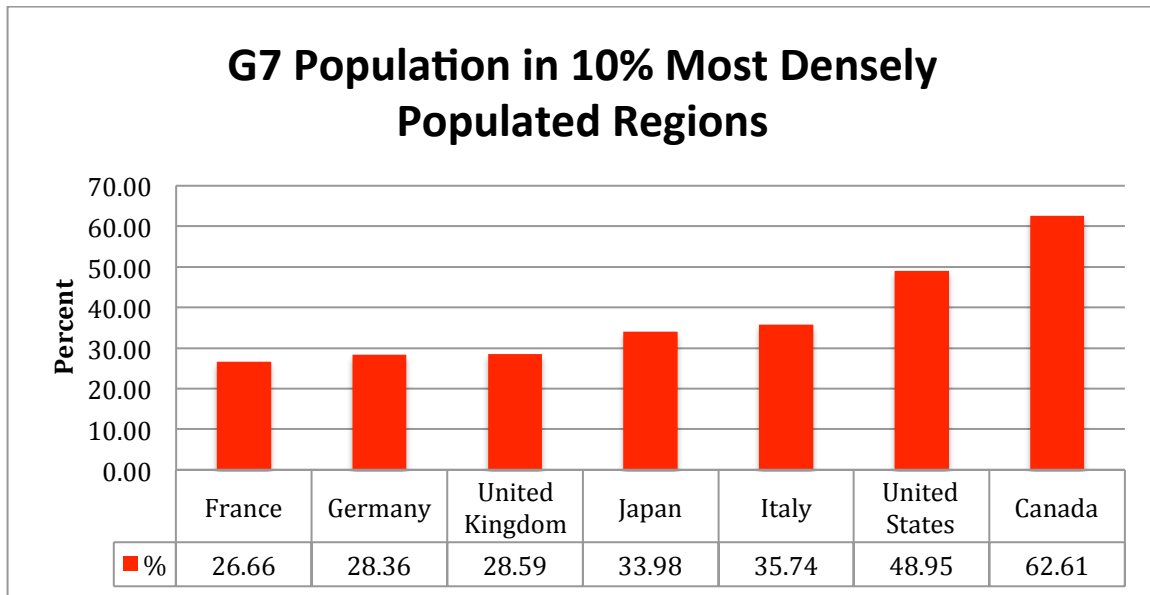


Figure 2. G7 Share of Population in Most Populated 10 Percent of Regions

Source: *OECD Factbook*, June 2014.

The US also has the median proportion of rural population in the G7. Italy, Germany, and France stand out for their large rural populations, signaling potential problems with broadband deployment, but these nations have more evenly distributed populations than Canada and the US (Figure 3).

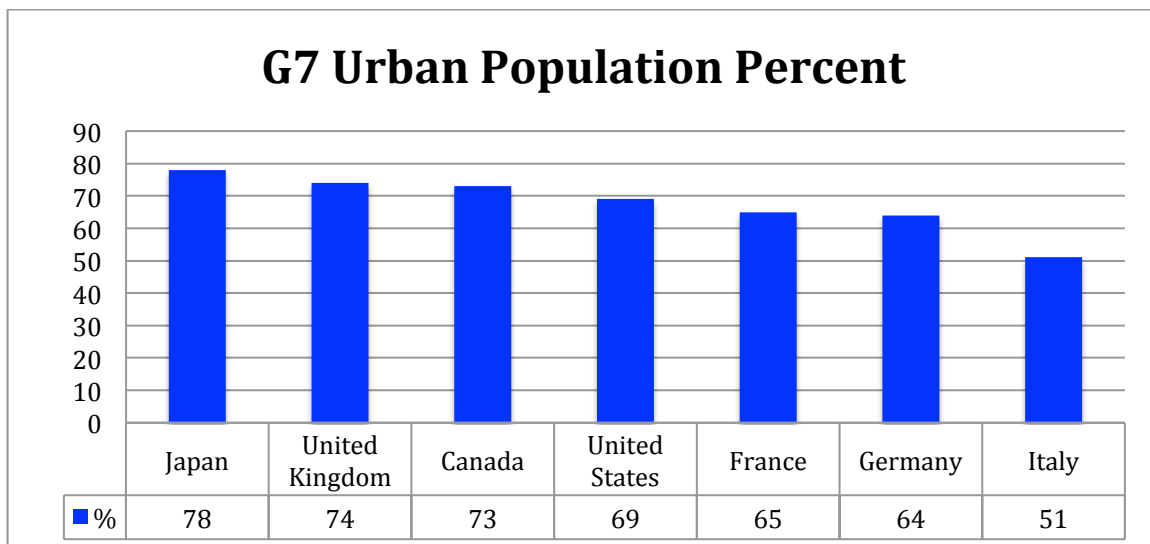


Figure 3. G7 Urban Population Distribution in Percent

Source: *OECD Factbook*, June 2014.

Together, these two charts show that the rural population in the US is both relatively large (as a proportion of the total population) compared to the rest of the G7 and also significantly more dispersed. Canada has a more dispersed rural population than the US, but it does not have as many rural residents as a proportion of total population as the US.

Italy, Germany, and France have proportionately more rural residents than the US, but their rural regions are not as dispersed as those in Canada and the US. To put this finding in simple terms, the US has a lot more people living on 10-acre lots than other countries do and a lot fewer living in high-rise apartment buildings.

A quick examination of population distribution is included in the *Whole Picture* report I wrote that was published by the Information Technology and Innovation Foundation (ITIF) in 2013.⁹ It studies the relative density of cities in Organisation for Economic Co-operation and Development (OECD) nations, from which we can extract data relevant to the G7 (Figure 4).

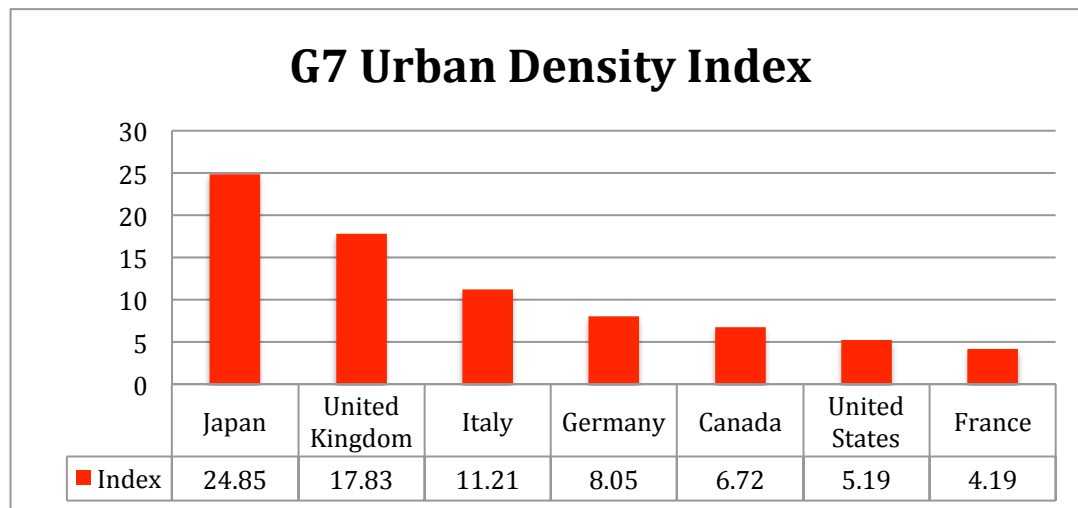


Figure 4. G7 Urban Density Index

Source: ITIF, *Demographia*.

The ITIF urban density index is an assessment of the mean density of all urban and suburban areas with more than 1,000 people per square mile.¹⁰ A highly concentrated urban population profile reduces costs to serve urban residents—new fiber costs less than \$200 per residence passed in Hong Kong versus \$700–2,000 per residence in US cities and suburbs. It also increases costs to serve each rural resident; on net, high urban density reduces nationwide service costs, especially when rural population is low.

Perhaps the best way to assess population distribution is in terms of the rural density rather than urban or suburban density. By number of rural residents per square kilometer of arable land, a standard measure in population studies, we see stark contrasts within the G7, ranging from near 1,000 (the high limit by definition) in Japan to 14 in Canada (Figure 5).

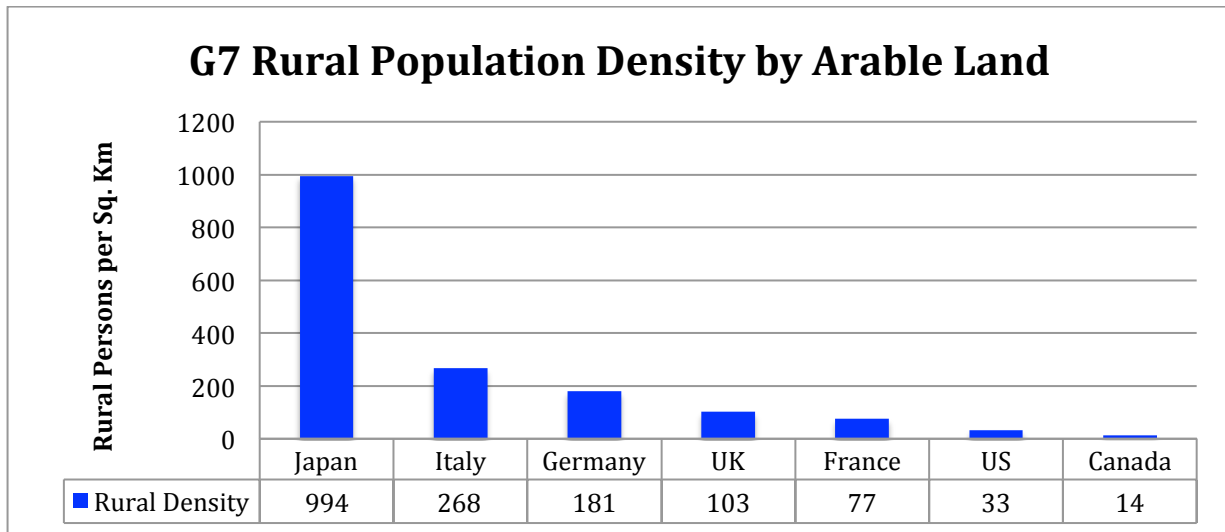


Figure 5. G7 Rural Persons per Sq. Km. of Arable Land

Source: World Bank, *The Little Green Data Book 2011*.

While much of the US population lives in relatively high-density areas, our urban centers are less concentrated than those in most G7 nations and our rural residents are much more dispersed as well. While the G7 nations are roughly comparable, there are still meaningful differences in several dimensions of comparison.

Superficial examination suggests that distance to major Internet Exchanges varies considerably across the G7. This factor has a major impact on service costs. An approximate measure—derived from the number of exchanges per nation, the rural population, and average rural density—suggests a range from 14,082 square km per exchange in Japan to 222,236 in Canada, with the US at the high end with 185,924.

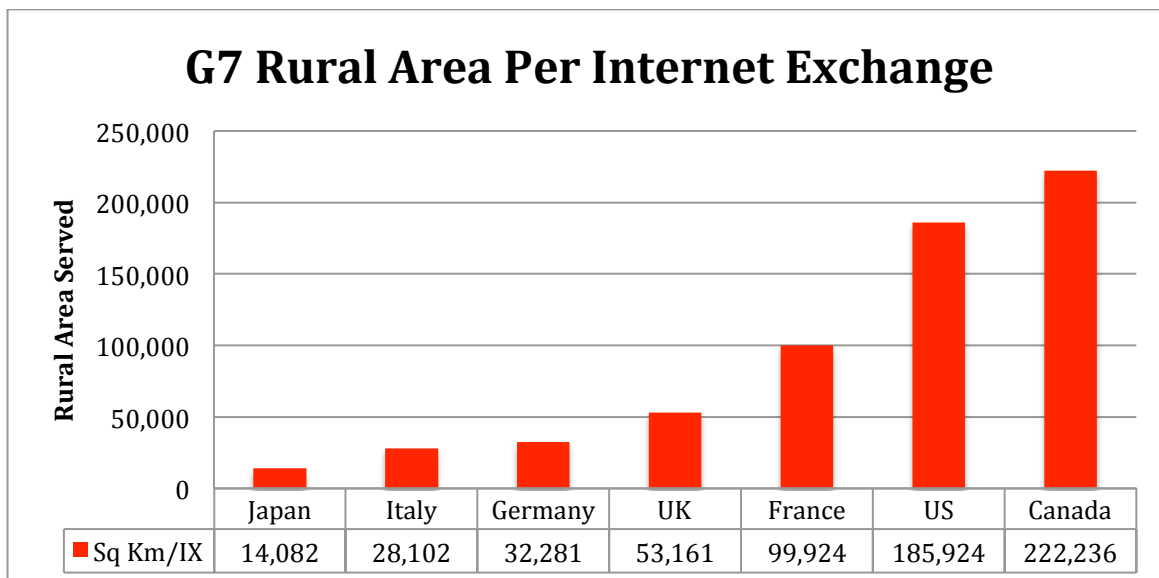


Figure 6. Rural Area Served by Each Internet Exchange Point in Nation or Nearby

Sources: Author's calculations from World Bank, *The Little Green Data Book 2011*; and Aemen Lodhi et al., "Using PeeringDB to Understand the Peering Ecosystem," *ACM SIGCOMM Computer Communication Review (CCR)* 44, no. 2 (April 2014): 21–27.

Superficial examination suggests that distance to major Internet Exchanges varies considerably across the G7.

This is not a precise tally, but it is clear that a dispersed population is more expensive to serve with wired broadband than a compact one. The dispersed rural population is one reason the US installs more new fiber optic cable each year than any comparable region.¹¹

Technical Infrastructure. Before broadband, most homes in the G7 were wired for telephone service, and some were wired for cable TV. The United States, Canada, Japan, and the UK led the G7 in cable deployment, and the OECD average deployment was roughly half the US deployment (Figure 7).¹²

The starting point suggested that DSL would become the most popular form of broadband for developed nations since its wire plant was most prevalent. It also suggested that the US and Canada, and to a lesser extent, the UK, would be excellent candidates for a facilities-based competition model, but other countries would not be.

The dearth of cable in most of the developed world also suggested that fiber networks would be likely to appear earlier in noncable countries, since the greater capacity of cable would make fiber builds less attractive where it existed and fiber more compelling where it did not.

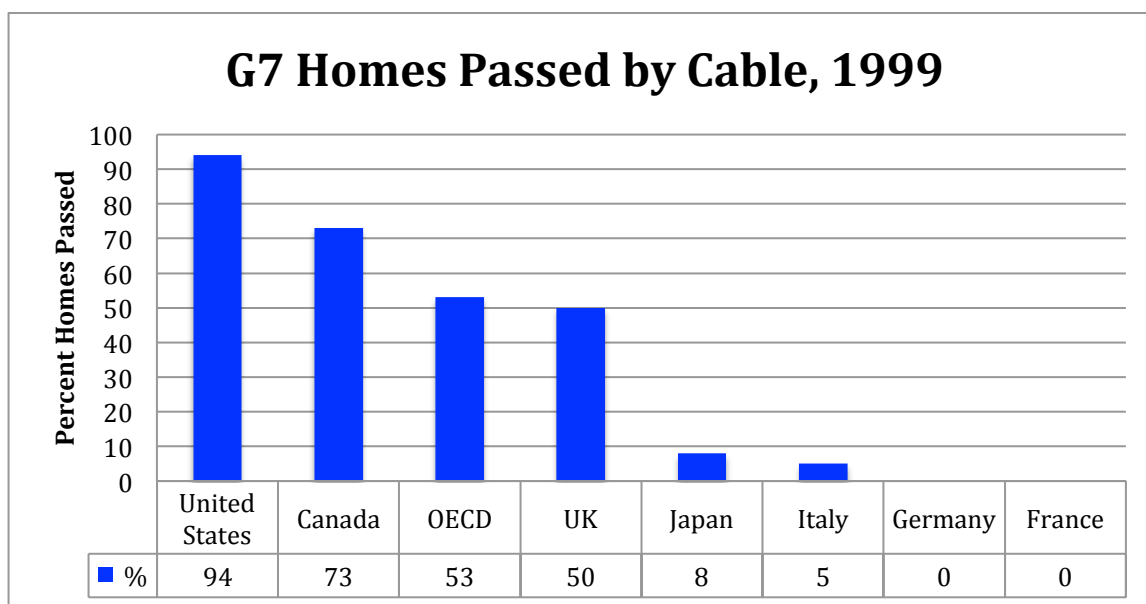


Figure 7. Cable TV Coverage in 1999

Source: OECD, *OECD Communications Outlook 2003*.

While the US led the G7 in cable TV in 1999, it was only middling in cellular telephone deployment, a trend that took off most rapidly in nations with poor wired telephone service (Figure 8).

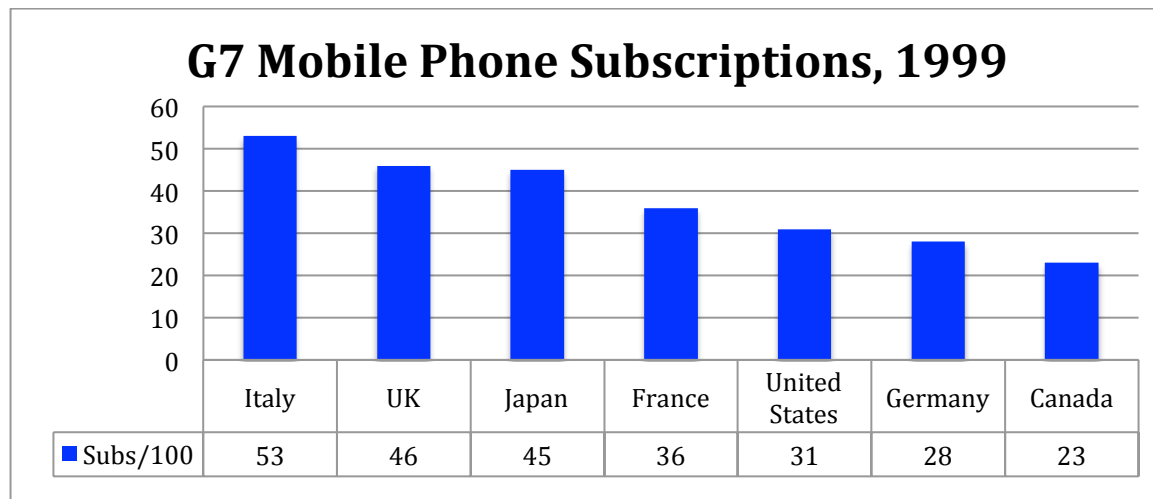


Figure 8. Mobile Subscriptions per 100 People in 1999

Source: World Bank, “Mobile Cellular Subscriptions per 100 People,” <http://data.worldbank.org/indicator/IT.CEL.SETS.P2?page=2>.

At the end of 1999, 120 geostationary satellites were in orbit, six of which were intended to provide high-speed Internet access. Half of the six Internet satellites served the United States and Canada, but none served the other G7 nations:

- AMC 5 (North America)
- Eutelsat 115 West A (North America)
- AMC 4 (Continental US, Mexico, and northern South America)
- Arabsat 3A (Middle East)
- Asiasat 3S (South Asia)
- Africasat 1 (Africa and Asia)¹³

With extensive deployment of telephone, cable, mobile, and satellite, the US was in a very strong position to develop a robust and diverse broadband marketplace as demand for high-speed Internet service began to grow.

Policy Frameworks. The US and Canada inherited two regulatory frameworks from the prebroadband era: a common-carriage framework for telephone networks and a contract-carriage framework for cable TV networks. Thus, the formation of broadband policy in the US in the 1990s was a debate over the merits and demerits of two very different but equally established frameworks that already applied to the two networks over which broadband service was supplied.¹⁴ Telephone service in these two countries was supplied by privately owned, highly regulated monopolies. The US-Canada model—termed the “Pioneer Model” in this study—reserves subsidies for some research and development and rural network expenses and relies on private capital to finance the most advanced urban systems. The primary government role in these nations is to accelerate diffusion of advanced technologies to rural areas.

Europe and Japan inherited an entirely different framework, as government-owned monopolies in the process of privatization supplied telephone service and cable was rare. Consequently, the model developed for the privatization of the telephone network was reflexively applied to broadband without deep consideration of alternatives. In many respects, the framework used by the US to complete the Bell System divestiture resembles the privatization model; local-loop unbundling (LLU) is a common element. In Europe, subsidies are often used to inject advanced technologies into urban markets, but they are also used to fund rural systems.

The US and Canada inherited two regulatory frameworks from the prebroadband era: a common-carriage framework for telephone networks and a contract-carriage framework for cable TV networks.

In all G7 nations, regulatory models changed over time. The initial EU regulatory model was based on Thatcher-era UK mechanisms developed to privatize British Telecom (BT) and on subsequent desires to use the BT network to leverage broadband competition. The common EU framework was “transposed” into national law in each member state. National regulatory authorities (NRA) then modified common policy to meet national goals. In North America and Japan, policy can be adapted to national goals without the involvement of a super-governmental entity such as the European Commission.

Progress

Initial starting points produce different effects at each stage of technical marketplace development. One obvious effect takes place in nations without cable: while they are able to supply basic broadband in both urban and rural areas over telephone wire, NGA is a challenge that can be met only with large-scale installation of new fiber optic wiring. Skipping cable TV puts the nation in a better position to meet the challenge of ultra-high-capacity networking than it would be if it had inherited a cable TV system.

Similarly, nations with poor telephone systems—such as Italy—are more highly motivated to adopt mobile phones than nations with higher-quality public switched telephone networks (PSTN).

For purposes of analysis, it is useful to think of broadband progress as undergoing three fundamental stages of development:

Stage One: Basic Broadband

1. Desktop computer is the standard networking device.
2. Baseline copper twisted pair for telephone service enables basic asymmetric DSL (ADSL) at capacities of 256 Kbps to 6 Mbps.
3. Baseline copper coaxial cable in combination with fiber optics enables DOCSIS 1.x and 2.x cable modem service at capacities of 1 Mbps to 20 Mbps.
4. Wireless broadband is limited to Wi-Fi with less capacity than common wired networks.
5. Basic CDNs appear to offload core networks.

Stage Two: Advanced Broadband

1. Laptop computers become common networking devices.
2. Partial replacement of copper pair with fiber and use of vectoring increases capacity to 40 Mbps or more for DSL.
3. Channel bonding increases DOCSIS 3.x capacity to 100 Mbps or more.
4. LTE enables mobile broadband to compete in speed and coverage with speeds in excess of 20 Mbps.
5. Wi-Fi outpaces wired broadband capacity.
6. Value-added CDNs optimize applications for varied devices.

Stage Three: Pervasive Broadband

1. Most end-user Internet connections are wireless.
2. Tablets, smartphones, sensors, and appliances are the most common networking devices.
3. Mobile networks reach hundreds of Mbps in fixed and mobile configurations.

4. Wired backhaul reaches gigabit capacities.
5. Cloud computing is embedded in the basic Internet experience.

The elements of each stage in this progression are interdependent, with each reinforcing the role of the others and the combination creating the push to advance to the next level. We want to see developments in each stage that maximize social benefits within the stage and also create momentum toward the following stage.

Leadership

One common recipe for policy success comes from accurately predicting future trends and facilitating them, but this is harder than it appears to many. Technology forecasters are divided on the question of whether the future of networking will be predominately wired or wireless; in the technology community, there is a broad consensus that wireless will dominate, but in policy circles wired still commands many adherents.¹⁵

This is an important question that plays out in many areas from spectrum policy to subsidy programs for wired networks. As the OECD data suggest, network policy has a long history of regarding wired as the dominant modality and wireless as an afterthought. Many policy mavens still regard wireless as the red-headed stepchild of networking, even as smartphones and tablets have become the “first screen” for many and the only screen for some.¹⁶

Australia’s ill-fated National Broadband Network is illustrative. That nation went whole-hog for a nationwide Gigabit Passive Optical Network (GPON) FTTH network, only to encounter ballooning costs and ever-increasing buildout delays. This contributed to the ouster of a government and the recalibration of the plan toward a more modest multiple-technology model. A side effect of the NBN was a large cash payment to former incumbent Telstra that was used to upgrade its mobile network. Arguably, Australia now has the world’s best LTE network thanks to a policy blunder that overvalued FTTH and undervalued mobile and dynamic competition.¹⁷

The midway position on the future of networking predicts increased penetration of fiber to businesses and neighborhoods alongside a fundamentally wireless edge; the current generation of college students already consists of a majority who have used computers since early childhood but have never connected an Ethernet cable. This appears to be the likely scenario that policy should drive toward, although we will not know what the future holds until it arrives.

Broadband Coverage

The first policy question about broadband networks concerns the extent of network deployment or coverage; until there is a network, there is no need to concern ourselves with subscriptions, performance, prices, or benefits. In most of the G7, broadband coverage by services that permit basic utilization of the web has been accomplished. In the US, the National Telecommunications and Information Administration (NTIA) reports 100 percent nonsatellite broadband availability.¹⁸ The questions that remain simply concern the details. It is nevertheless instructive to see how we got where we are. The research arm of the OECD assembles the most useful historical data on broadband coverage.

Homes Passed by Basic Broadband Technologies

OECD data on homes passed by technology is still at least five years old; OECD data are therefore useful as a guide to broadband deployment only in the Basic Broadband stage.

OECD DSL deployment data do not distinguish types of DSL and have not been updated since 2009, but very little (if any) new DSL has been installed since then.

As expected, DSL coverage is most extensive in nations with small rural populations and little or no cable modem service (Figure 9). DSL coverage is measured in various ways across the OECD (for example, by population, by household, and by number of lines).

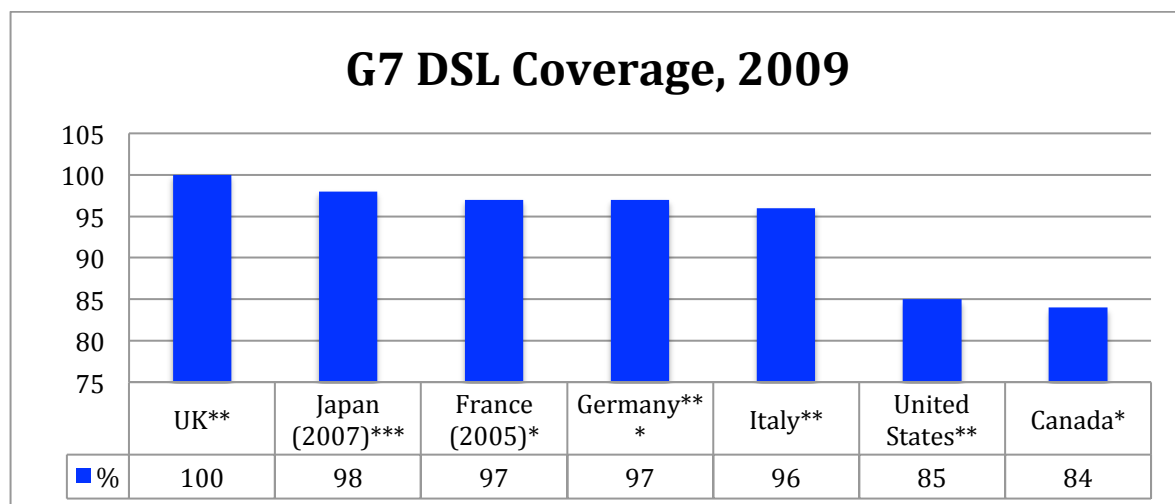


Figure 9. G7 DSL Coverage in 2009 (Except as Noted)

Notes: *Population; **Lines; ***Households.

Source: OECD, "OECD Broadband Portal."

OECD cable modem data are similarly dated and include no entry for Japan, which is known to have extensive cable coverage (Figure 10). According to the Japan Cable Television Engineering Association (JCTEA), cable modem passed nearly half of Japanese homes by 2010. OECD and JCTEA cable deployment data are for all types of cable modem service, the Basic Broadband stage.

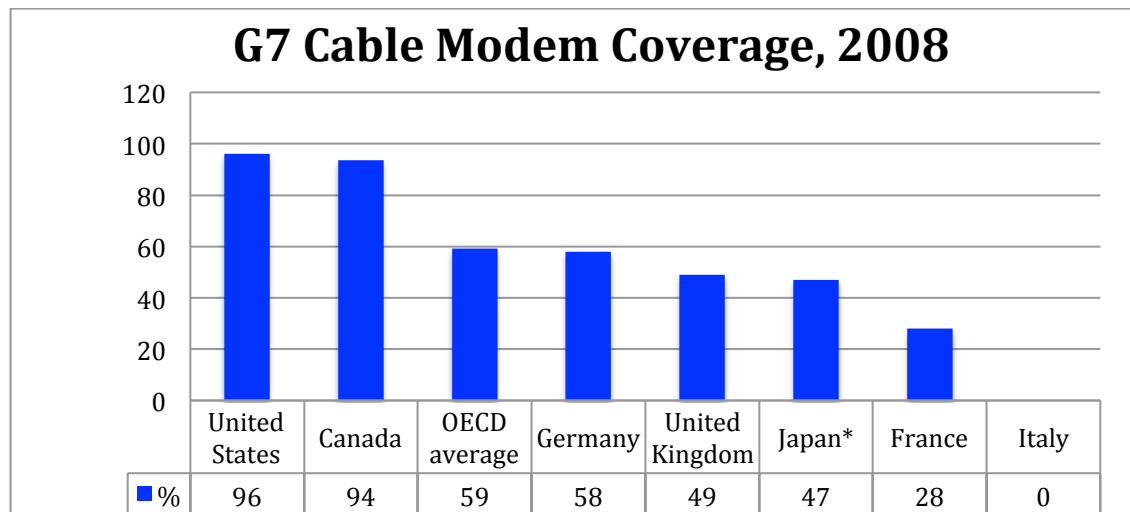


Figure 10. G7 Cable Modem Coverage in 2008

Sources: OECD, “OECD Broadband Portal”; and Hiroshi Asami, “Cable TV in Japan: Competitive Status in Full Digital Age; Migration for IP Video.”

OECD fiber coverage is accurate only up to 2009. Extensive fiber deployment in the US has more than doubled this figure today, according to government reports (Figure 11). Current government reports from the European Union suggest that OECD overstated FTTH coverage in the past.

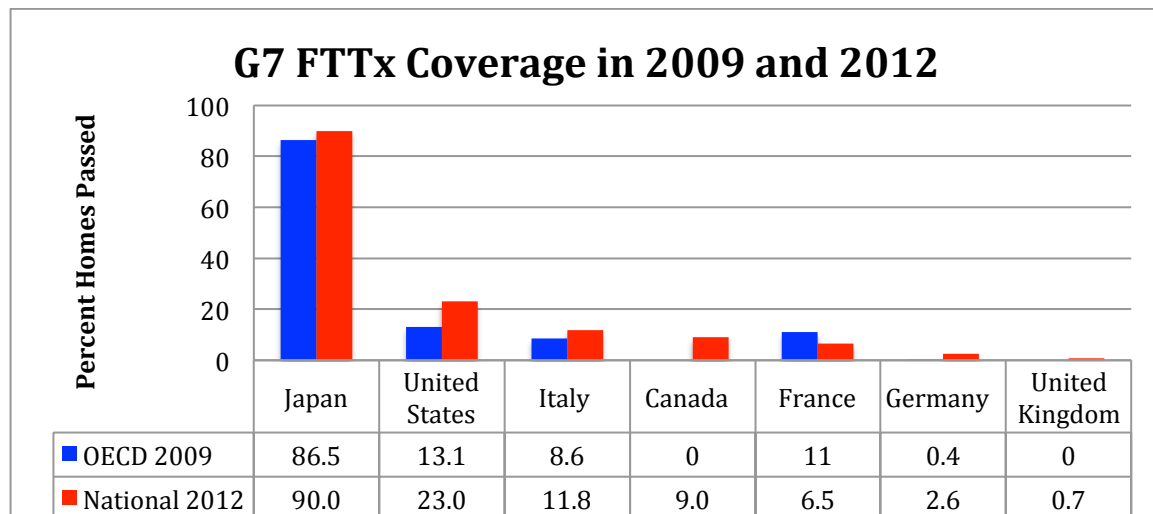


Figure 11. G7 Fiber Coverage in 2009 and 2012

Sources: OECD, “OECD Broadband Portal”; NTIA and FCC, “Broadband Availability in Urban vs. Rural Areas”; Point Topic, *Broadband Coverage in Europe in 2012*; and Canadian Radio-Television and Telecommunications Commission, *Communications Monitoring Report 2013: Broadband Availability and Adoption of Digital Technologies*.

Within the EU, there is considerable inconsistency in the reporting of VDSL Fiber-to-the-Cabinet (FTTC) and Fiber-to-the-Home or -Basement (FTTH/B). The term “FTTx” includes both modes of fiber. VDSL is actually a hybrid of copper and fiber, just as cable modem is a hybrid of coaxial cable and fiber, but FTTx excludes cable modems.

OECD’s mobile coverage data are similarly dated, ending in 2009 with 3G wireless, a technology best regarded as Basic Broadband since its top speeds are less than 4 Mbps (Figure 12).

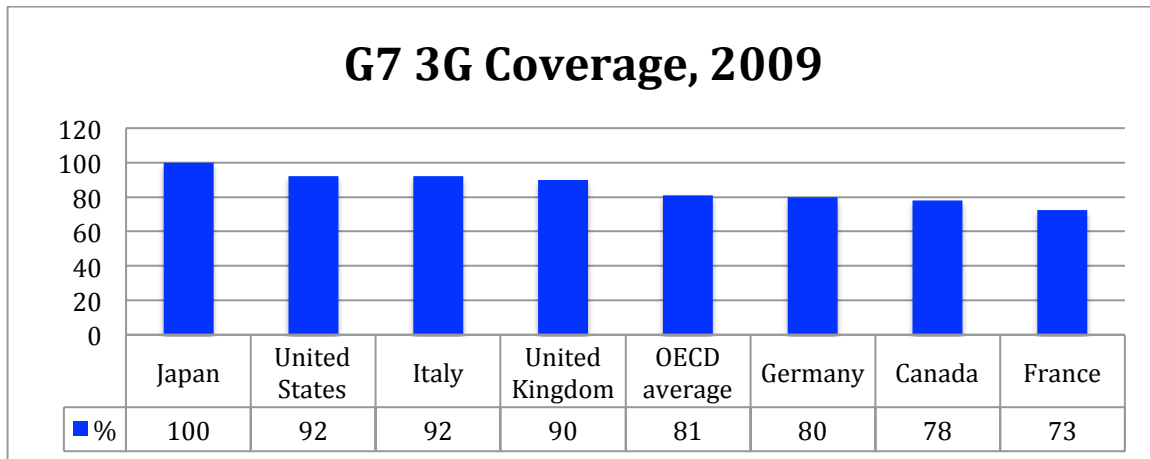


Figure 12. G7 3G Mobile Coverage in 2009
Source: OECD, "OECD Broadband Portal."

Number of Providers in the Basic Broadband Stage

Bimodal coverage can be calculated on the basis of the lesser of the two largest coverage values (typically DSL and cable, but DSL and fiber in the case of Japan).

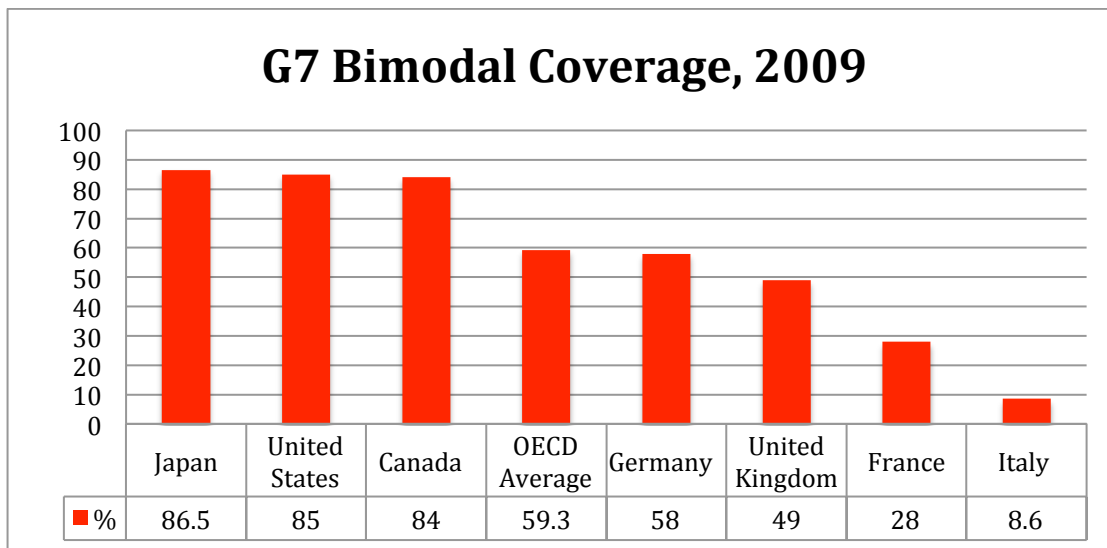


Figure 13. G7 Bimodal Competition in 2009
Source: OECD, "OECD Broadband Portal."

We can calculate a trimodal coverage table from using the minimum of DSL, cable, and 3G for most countries and DSL, fiber, and 3G for Japan (Figure 14).

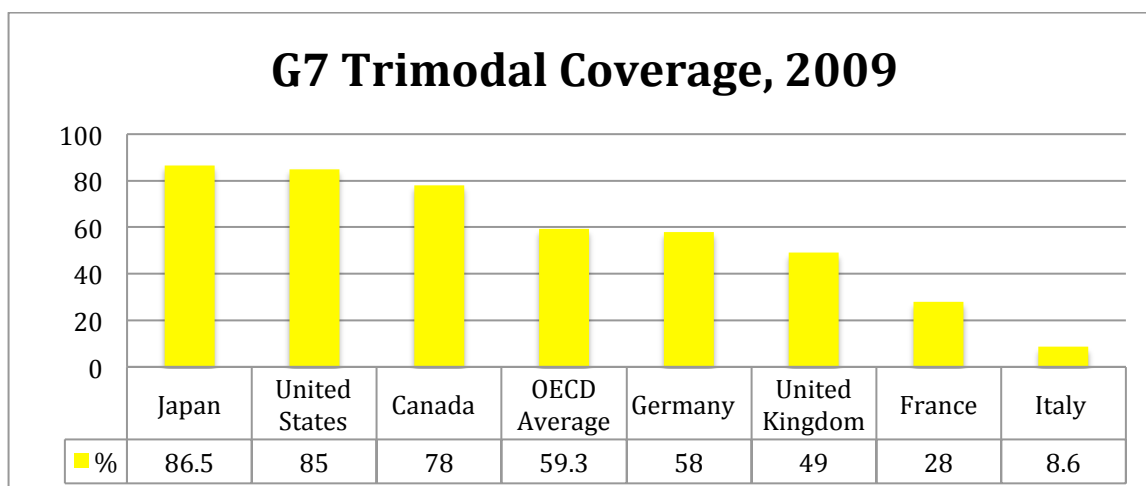


Figure 14. G7 Trimodal Competition in 2009

Source: OECD, "OECD Broadband Portal."

The ranking order is the same as for the bimodal table, but the gap between the US and Canada is wider owing to lower 3G coverage than DSL coverage in Canada.

Number of Providers in the US

The National Broadband Map calculates multimodal competition on the basis of the number of providers capable of supplying broadband by its definition (10 Mbps download) both by technology and independent of technology.

These measures have somewhat limited application as they do not factor the effects of usage limits on some wireless accounts that constrain their usefulness for such applications as video streaming that comprise 2 percent of Internet usage by time. The National Broadband Map data suggest that rural wireless broadband coverage is somewhat limited, but this is changing.

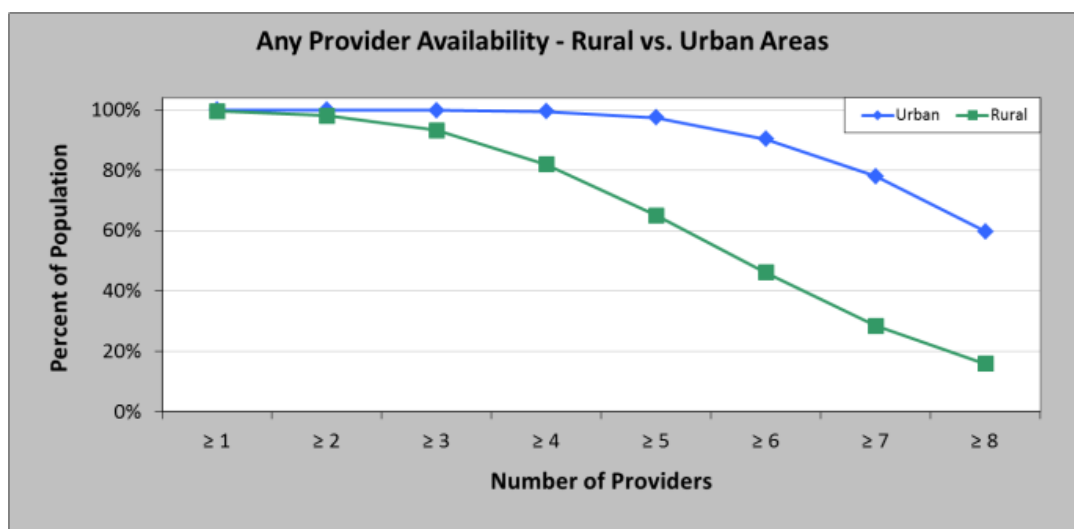


Figure 15. US Urban versus Rural Broadband Competition

Source: NTIA and FCC, "Broadband Availability in Urban vs. Rural Areas."

By NTIA's definition, 100 percent of urban America has access to at least four providers of broadband service, 100 percent of rural America has access to at least one, and 95 percent of rural America has access to at least two (Figure 16). These options include wireless at the requisite speed, but not satellite.

The state of broadband competition has thus improved dramatically over its condition in 2009 when OECD stopped collecting coverage data. Surprisingly, the National Broadband Map finds that many Americans have three or more choices of wired broadband providers: more than 65 percent of those are in urban areas and nearly 20 percent in rural areas (Figure 16); this is a consequence of the National Broadband Map's inclusion of all competitive local exchange carriers (CLEC) as options across entire census tracts in which a single connection exists.¹⁹

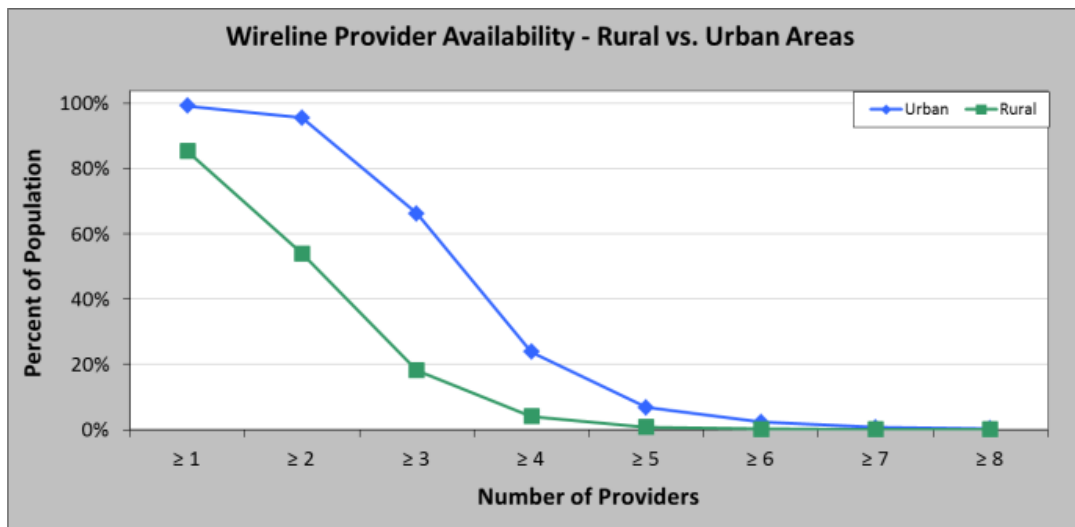


Figure 16. US Access to Multiple Wired Broadband Choices
 Source: NTIA and FCC, "Broadband Availability in Urban vs. Rural Areas."

Deployment of Advanced Broadband in the G7

Advanced Broadband is termed "next-generation access" (NGA) in international policy discourse. This form of broadband is generally defined as any broadband technology with a gross download capacity of 25–30 Mbps or higher, whether shared or unshared. Common NGA technologies are:

- VDSL (Hybrid fiber/copper DSL, vectored, short distance, and/or pair-bonded, including VDSL2+)
- DOCSIS 3.x at 30 Mbps (shared) and faster
- xPON or Optical Ethernet at any speed
- 3.9G/4G/LTE mobile broadband at 25 Mbps and above

OECD has declined to collect data on leading-edge networks, so we turn to the regional and national government authorities for information on deployments in the G7 as of the end of 2012.

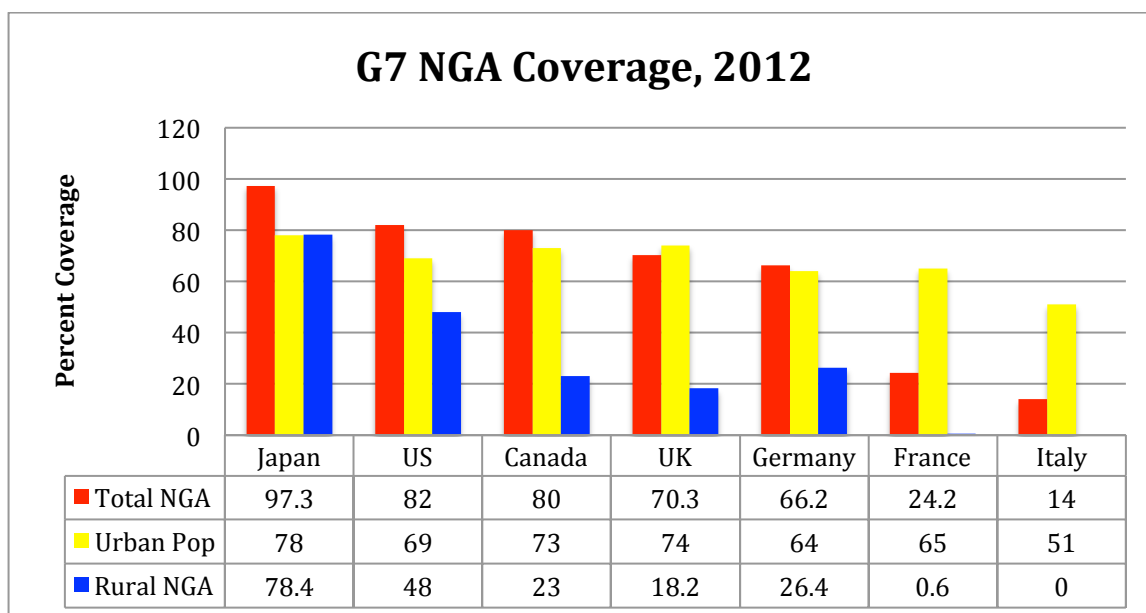


Figure 17. G7 NGA Coverage, 2012

Sources: Point Topic, *Broadband Coverage in Europe in 2012*; NTIA and FCC, “Broadband Availability in Urban vs. Rural Areas”; Ministry of Internal Affairs and Communications, *White Paper 2013: Information and Communications in Japan*; Canadian Radio-Television and Telecommunications Commission, *Communications Monitoring Report 2013: Broadband Availability and Adoption of Digital Technologies*; and World Bank, “World Development Indicators: Rural Environment and Land Use,” 2014.

Japan is the leader in total NGA coverage thanks to its 10-year commitment to a pervasive FTTH network based on xPON technology, but the US and Canada are close behind on the strength of their diverse broadband strategies.

NTIA’s National Broadband Map details the gap between urban and rural NGA coverage, an area of immediate government concern as long as rural broadband markets remain difficult to serve.

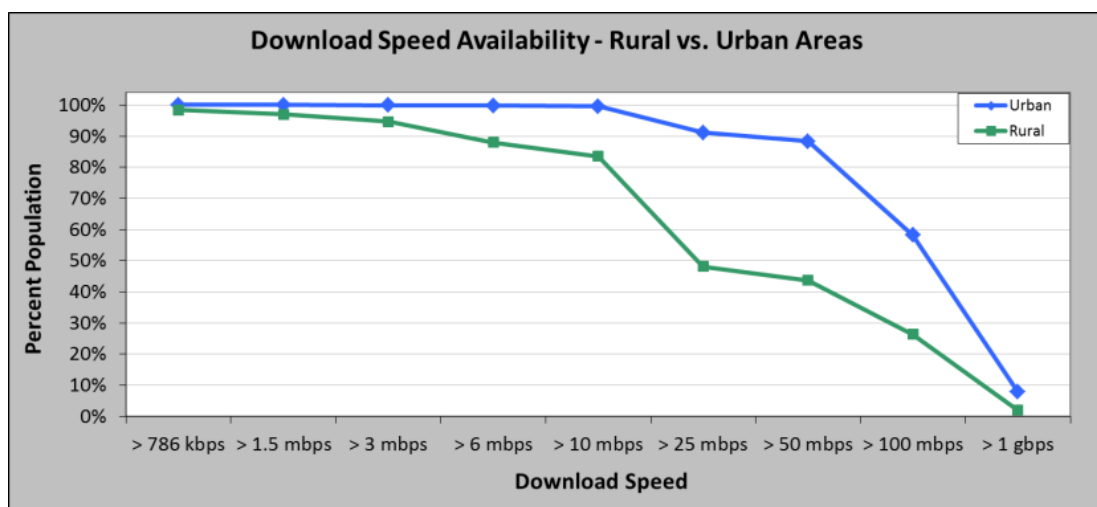


Figure 18. US Urban and Rural Broadband by Capacity, 2012

Source: NTIA and FCC, “Broadband Availability in Urban vs. Rural Areas.”

Advanced DSL. This category includes VDSL, VDSL2, VDSL2+, and Vectored DSL, technologies that are commonly lumped together as “VDSL.” They primarily differ from baseline

ADSL in terms of capacity: typical capacities for ADSL are less than 12 Mbps, while VDSL typically provides 20–80 Mbps; the highest speeds being enabled by vectoring. A more advanced form of DSL is G.Fast, with theoretical capacities up to 1 Gbps under ideal conditions (copper loops less than 500 feet).

The capacity of all forms of DSL is to a great extent a function of the length of the copper wire or “loop” connecting customer premise to the DSL access multiplexor. ADSL loops are commonly 5,000–10,000 feet, while VDSL loops are less than 3,000 feet long and the G.Fast loop is hundreds of feet. VDSL achieves higher capacity than ADSL through a combination of techniques:

1. Shorter copper loops;
2. Advanced signal processing; and
3. Doubling copper wire pairs (“pair bonding”).

In many instances, networks classified as FTTP are actually combinations of Fiber to the Basement (FTTB) in high-rise buildings and VDSL or copper Ethernet from the basement to the apartment. The European Commission classifies VDSL as fiber (FTTx) in many publications.²⁰

A recent study by the University of Pennsylvania Center for Technology, Innovation, and Competition (CTIC) credits VDSL with increasing broadband capacity in many European nations without aggravating the “digital divide.”²¹ It recommends emphasis on cable and VDSL for egalitarian reasons.

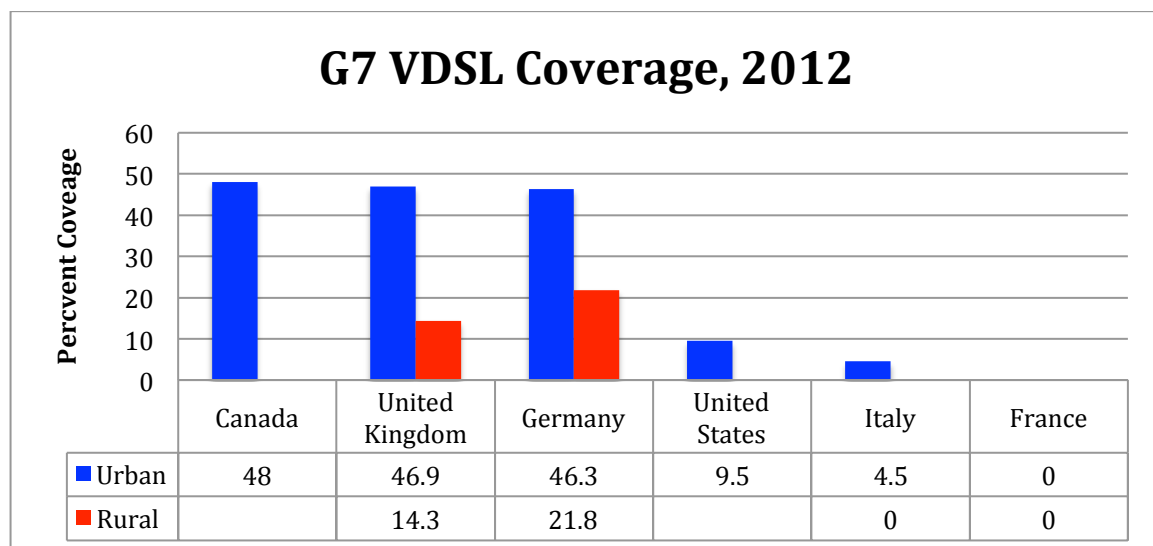


Figure 19. G7 VDSL Coverage, 2012

Sources: Point Topic, *Broadband Coverage in Europe in 2012*; NTIA and FCC, “Broadband Availability in Urban vs. Rural Areas”; and Canadian Radio-Television and Telecommunications Commission, *Communications Monitoring Report 2013: Broadband Availability and Adoption of Digital Technologies*.

This chart appears to understate VDSL availability in the US; consultants such as Leichtman Research say nearly a million Americans convert from ADSL to VDSL every quarter.²²

DOCSIS 3.0. The third generation of cable modem service, DOCSIS 3, enables users to share standard capacity of 160 Mbps as well as additional configurations up to 1 Gbps or more. Service providers sell services in capacity tiers, typically at 20, 30, 50, and 100 Mbps. As many as 100–200 households can share a 160 Mbps DOCSIS 3 without significant degradation, but service

providers can also limit sharing by “node splits” if they wish. DOCSIS 3 is the most common form of NGA networking in the world today.

Not surprisingly, DOCSIS 3 is most widely used in the nations that were already wired for cable before broadband services were introduced, and its presence in a market tends to spur deployment of competitive facilities such as VDSL, FTTx, and LTE (Figure 20). DOCSIS 3 is also attractive in nations that regulate it more lightly than the twisted-pair telephone wire plant is regulated; US investor Liberty Global is on a buying spree for European cable companies to exploit this advantage.²³

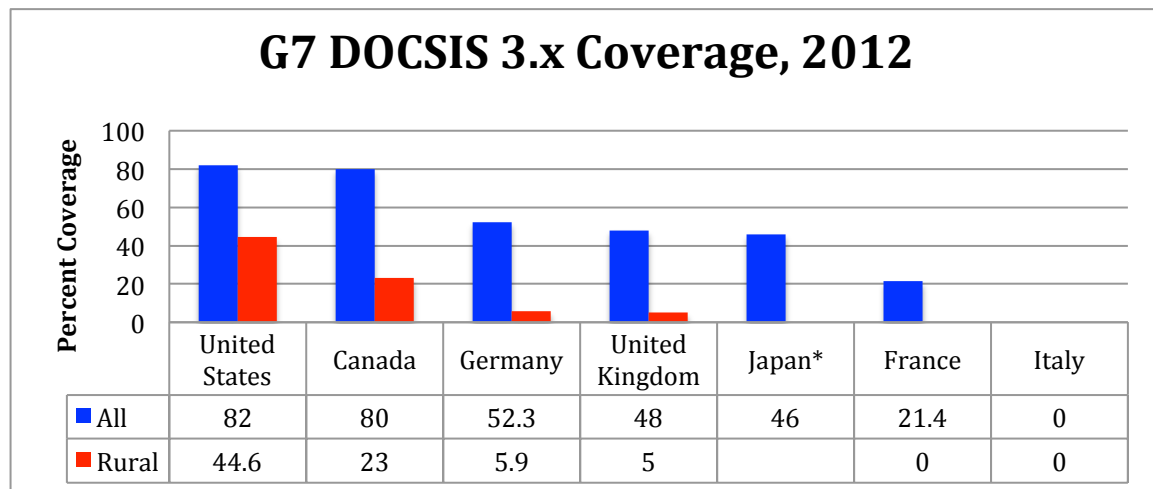


Figure 20. G7 DOCSIS 3.x Coverage, 2012

Note: Japan from 2010, Canada estimated.

Sources: Point Topic, *Broadband Coverage in Europe in 2012*; NTIA and FCC, “Broadband Availability in Urban vs. Rural Areas”; Canadian Radio-Television and Telecommunications Commission, *Communications Monitoring Report 2013: Broadband Availability and Adoption of Digital Technologies*; and Asami, “Cable TV in Japan: Competitive Status in Full Digital Age; Migration for IP Video.”

Fiber to the Home. Fiber to the Home and Fiber to the Basement are properly grouped together as FTTH/B, but VDSL in combination with Fiber to the Cabinet is considered in its own category, FTTC. The EU and NTIA/Federal Communications Commission (FCC) provide coverage data for FTTx in both urban and rural settings, but data on coverage for Canada are generally lacking and data for Japan are sparse because there is no reason to deploy VDSL in a nation already equipped with FTTH.

Canada’s data is inferred from the FTTH Council’s 2011 G20 scorecard. As it measured adoption, the score has simply been tripled. Japan reports NGA without distinguishing technology, but its FTTH/B score is virtually 100 percent. While FTTH/B can offer extremely high capacities—into the multiple Gbps—real implementations rarely offer more capacity than DOCSIS.

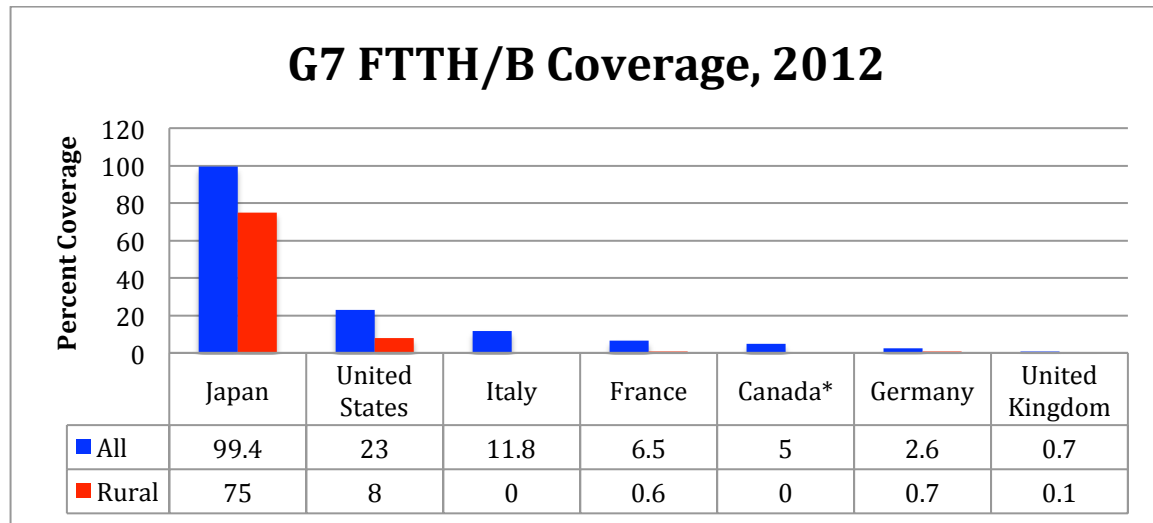


Figure 21. G7 FTTH Coverage, 2012

Note: *Canada's data are estimated from FTTH Council's 2011 G20 scorecard.

Sources: Point Topic, *Broadband Coverage in Europe in 2012*; NTIA and FCC, "Broadband Availability in Urban vs. Rural Areas"; and Ministry of Internal Affairs and Communications, *White Paper 2013: Information and Communications in Japan*; and Fiber to the Home Council, "Canada Joins Ranking of G20 Fibre Countries."

4G/LTE. The US was the first nation to deploy LTE at scale, beginning with the MetroPCS and Verizon deployments in 2010.²⁴ American firms were motivated to move to LTE because of CDMA's bandwidth limitations, but they were also allowed to upgrade because their spectrum was not burdened by a technology mandate as was the case in the EU. LTE spectrum was also made available in the US by the first Digital Television (DTV) spectrum auction in 2008.²⁵

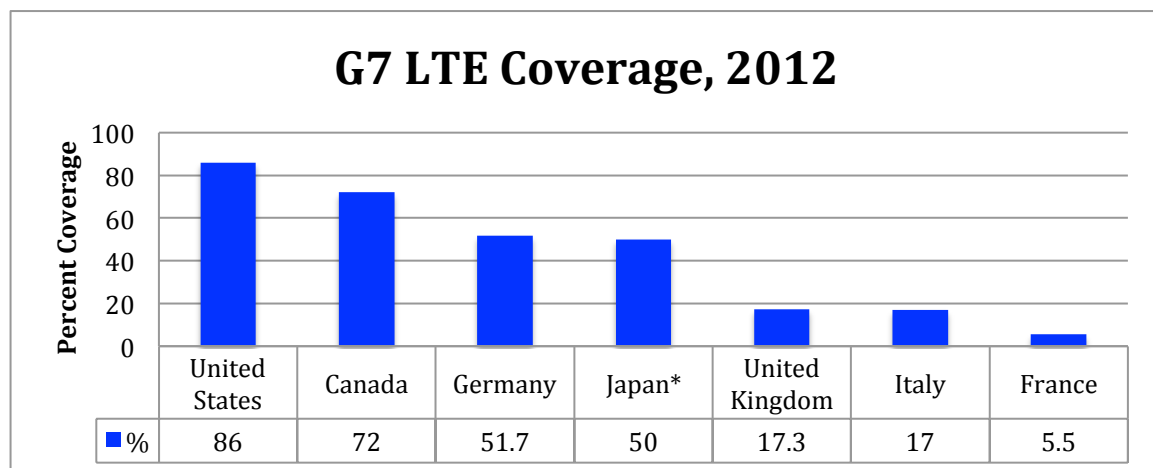


Figure 22. LTE Coverage in 2012

Note: *Japan data are estimated from start date and current data.

Source: Point Topic, *Broadband Coverage in Europe in 2012*; NTIA and FCC, "Broadband Availability in Urban vs. Rural Areas"; and Canadian Radio-Television and Telecommunications Commission, *Communications Monitoring Report 2013: Broadband Availability and Adoption of Digital Technologies*.

GigaMania: 1,000 Mbps Networking

Gigabit fiber connections are now relatively common in Japan and among Asian Tigers and are beginning to emerge in the Nordic countries that have long held a fascination for ultra-fast Internet connections. NTIA reports that 10 percent of urban American homes are passed by gigabit services, and carriers such as Verizon, Comcast, Century Link, and AT&T are in a position to offer gigabit services as demand develops.²⁶

Gigabit Projects. AT&T announced an initiative in April that would provide “GigaPower” connections in as many as 100 cities.²⁷ CenturyLink now offers gigabit services to business and residential customers in parts of 16 cities, with more locations to follow.²⁸ Comcast and other cable operators are quietly replacing coaxial cable with fiber in selected markets: “When customers in select parts of Comcast’s Northeast and Southern markets ask for the company’s fastest Internet speed of 505 megabits-per-second, the cable operator lays a fiber line to the customer’s home with capacity to offer the higher speed.”²⁹ Verizon’s FiOS service is already capable of providing gigabit network services to 18 million homes, and despite news that FiOS deployment has completed, the firm has a FTTH deployment plan that extends to 2019.³⁰

Consequently, it is reasonable to believe that gigabit networks will be common across America’s urban areas when and if demand calls for them. A great deal of activity is certainly taking place well ahead of substantial demand; the Gig.U third annual report chronicles a number of gigabit projects with various funding mechanisms (Figure 23).³¹ Commercial gigabit connections have been common in major American cities since the late 1990s.³²

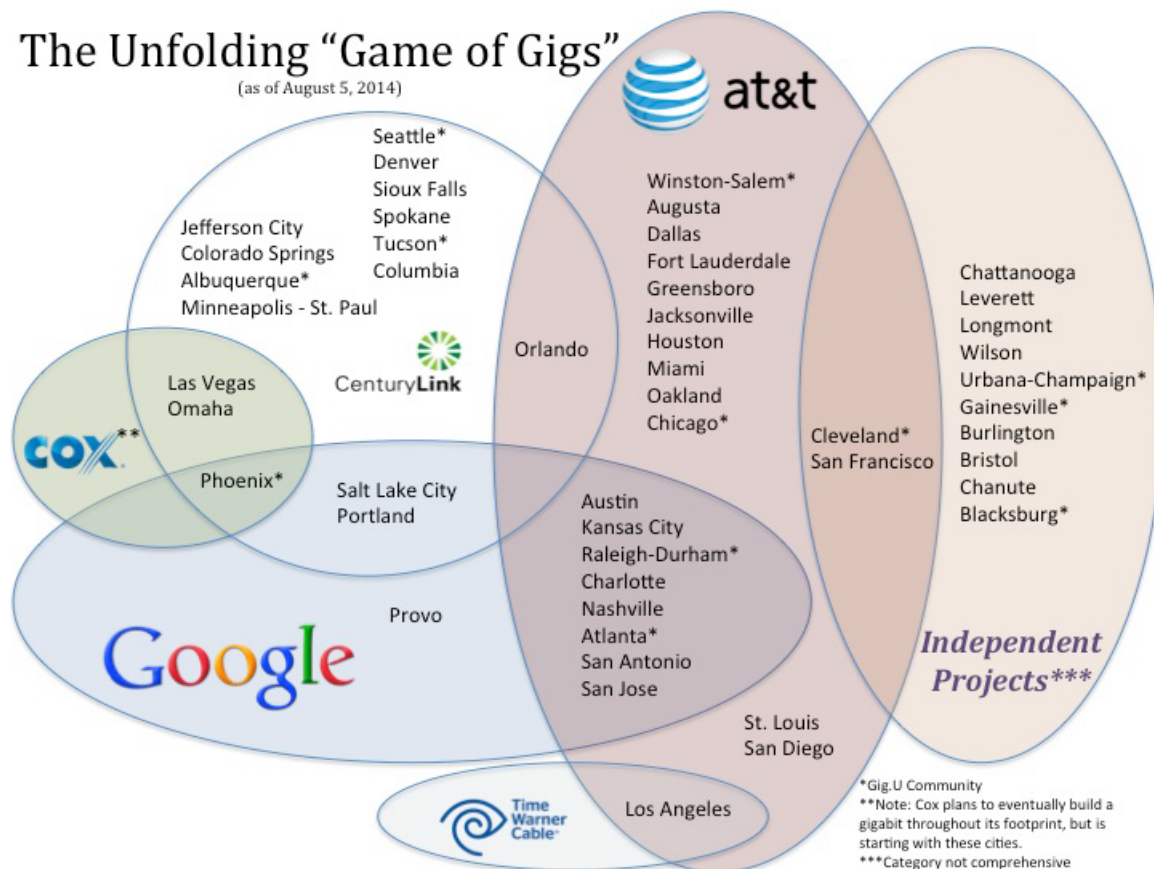


Figure 23. US Gigabit Network Deployments

Source: Gig.U, *From Gigabit Testbeds to the “Game of Gigs”: The Third Annual Report of Gig.U.*

Gigabit Utility. For gigabit networks to capture the imagination of the public, they will need to enable new applications. These applications would need to be exciting and capable of performing well with gigabit capacities but impractical at today's common 40–100 Mbps capacities. Such applications do not currently exist.

It is not difficult to imagine gigabit applications, and indeed the advent of gigabit local area networks and campus networks in the late 1990s stimulated attempts to visualize them. Systems of instantaneous browsing, holographic conferencing, virtual reality (like the Star Trek Holodeck), advanced medical imaging, and big data transfers fill the bill. *Cluetrain Manifesto* coauthor David Weinberg imagines gigabit networks supporting social surveillance:

If we had truly high-speed, high-capacity Internet access, protesters in Ferguson might have each worn a GoPro video camera, or even just all pressed “Record” on their smartphones, and those of us not in Ferguson could have dialed among them to see what’s happening. In fact, it’s pretty likely someone would have written an app that treats co-located video streams as a single source to be made sense of, giving us fish-eye, fly-eye perspectives anywhere we want to focus: a panopticon for social good.³³

But we have not seen this happening in areas that have gigabit networks. Regardless of future applications, today’s videoconferencing, remote learning, video streaming, cloud backup, and home security applications do not require gigabit networks; these applications are perfectly viable on today’s 40–100 Mbps networks.

NTIA reports that 10 percent of urban American homes are passed by gigabit services.

Some argue that despite gigabit networks’ lack of present utility it is nevertheless important to deploy them today to nurture the applications of tomorrow. “If you build the networks, the applications will come” is the mantra, and there could be some truth in it. Some firms are extending gigabit networks to residences today, so it should be possible to see applications appear shortly if the mantra is correct. The US

government estimates that 10.5 percent of urban American homes have access to gigabit networks today.³⁴

Gross Fiber Deployment

Prior to 2011, the year 2000 had featured the largest annual deployment of fiber optic cable in American history. Throughout the first decade of the 21st century, there was a glut of dark fiber in the US thanks to the ambitions of firms, such as Global Crossing, that tried—and failed—to cash in on the “fiber bubble.” The glut has been exhausted and the US is installing fiber optic cable at the rate of 20 million miles a year, greater than the rate for all of continental Europe, but behind the rate for China, with its large land mass, large population, and lower starting point.³⁵

Broadband Subscription Rates

Subscription rates for broadband are notoriously difficult to measure in a timely fashion on the global scale because of peculiarities in reporting and delays in publishing by OECD's research department. OECD reports subscriptions on a per-100-population basis, but US households are larger than those in most OECD nations, so US subscription rates tend to be understated in international measurements.

Subscription Rate

The most recent data from OECD say that 71.1 percent of Americans subscribe to a wired broadband service, roughly the same figure reported by the Pew Internet and American Life Project (Figure 24).³⁶ This figure reflects less interest in wired Internet in the US than in some other countries. Interest in the Internet is largely a function of age, literacy, and income. While the US has a smaller elderly population in relation to the working-age population of other G7 nations, it has greater income disparity.³⁷

There is also reason to believe that interest in the Internet is highest in nations with long winters, where indoor entertainment is more highly valued than it is in the US; Scandinavian nations show high interest in the Internet, for example.

Wired-only subscription data also hide the effects that greater smartphone penetration has on Internet use by Americans who rely on wireless networks. In addition to the around 70 percent of Americans who access the Internet via wired connections, 16–17 percent access it exclusively from mobile devices.³⁸

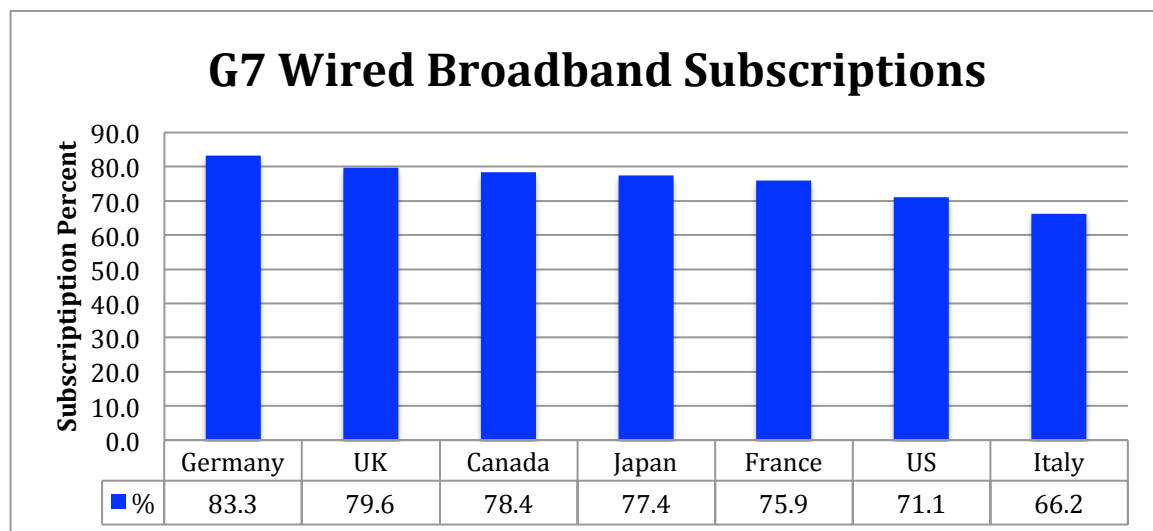


Figure 24. G7 Wired Broadband Subscription Rate

Source: OECD, *OECD Factbook*.

Subscription Rate by Technology

While most of the G7 accesses the Internet through DSL facilities, most Americans use cable modem services with higher speeds (Figure 25). Japan is the only G7 nation in which FTTH/B is the predominant form of Internet access, and this shows in that nation's performance

measurements (other than Ookla Speedtest, which ranks Japan fifth in average download speed). OECD ranks the UK higher than the US on fiber subscriptions by classifying VDSL as a fiber technology rather than the more advanced form of DSL that it actually is; much of America's fiber is Verizon FiOS, a technology that takes fiber all the way to the residence. Most fiber connections in France, Germany, and Italy are legitimate FTTH, but they are very scarce.

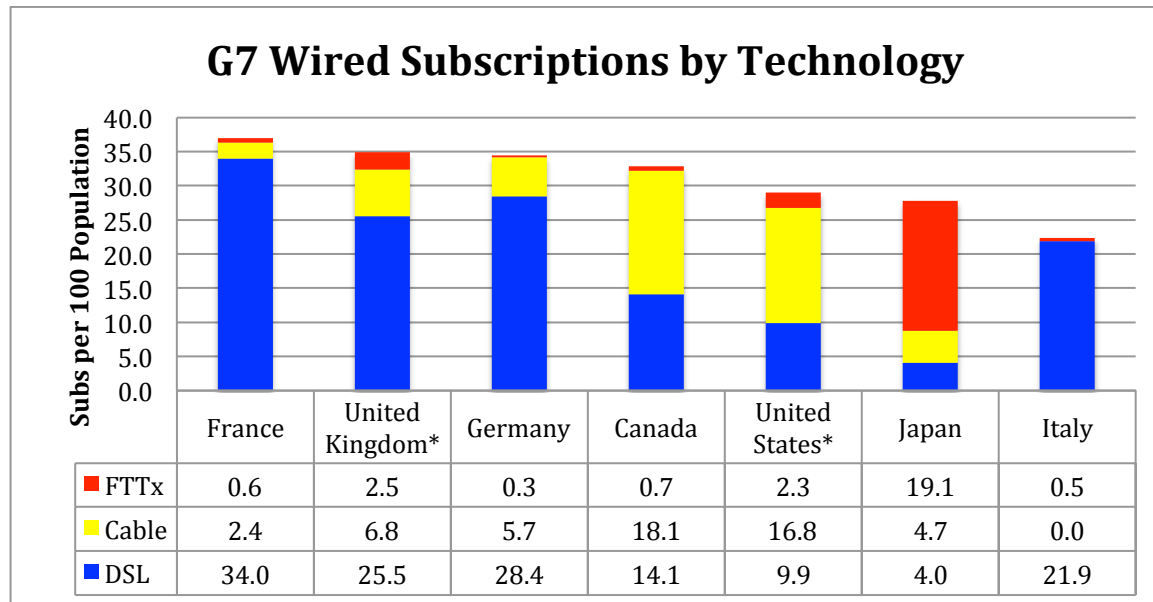


Figure 25. Wired Broadband Subscription Rate by Population and Technology, 2013

Note: *UK and US estimated by OECD.

Source: OECD, "OECD Broadband Portal."

As a percentage of all wired connections, Japan has the highest fiber preference at 68.5 percent, reflecting the nearly pervasive character of the Nippon Telegraph and Telephone (NTT) FTTH/B buildout (Figure 26). This buildout has proved beneficial to mobile operators who are often able to obtain inexpensive dark fiber from NTT to provide tower backhaul (the connection between the tower and the network).

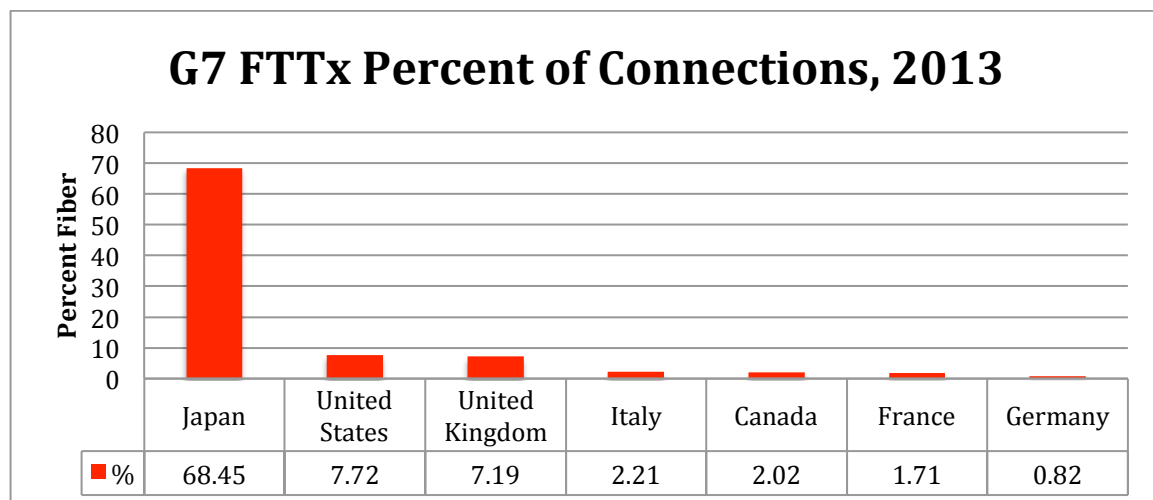


Figure 26. Fiber Subscriptions as Percent of All Broadband Subscriptions

Source: OECD, "OECD Broadband Portal."

One of the issues that bedevils broadband providers considering deploying fiber is the takeup rate, the percentage of potential customers who choose to switch to fiber from their previous plan or who subscribe to broadband for the first time. Carriers consider takeup rates proprietary information, so analysis is difficult.

The pattern of consumer indifference to extremely fast network services is international.

Some analysts estimate a 40 percent takeup rate for FiOS and even higher levels for Google Fiber, a network that relies on the Verizon-developed xPON technology. The OECD estimates a much-lower 25 percent rate (Figure 27). It is likely that the FiOS takeup rate is somewhat short of the 40 percent rate that Verizon anticipated. Google refuses to disclose takeup rates for its Kansas network, and takeup rates for municipal fiber networks tend to cluster at the most economical tiers.

The pattern of consumer indifference to extremely fast network services is international; Hong Kong Broadband Network Limited was not successful at attracting users to its fiber service until it offered promotional prices lower than DSL prices for users who recruited a friend. The HK \$13 per month promotional price it offered sent ripples through the local market, but they were short lived; shortly after the promotion ended, carriers went back to renting Wi-Fi routers for HK \$13 per month above the price of broadband connections.³⁹

The issue with fiber take rates reflects the gap between consumer preferences and the desires of fiber fanatics; surveys often show consumers completely unaware of basic broadband service parameters such as upload and download speeds.⁴⁰ Increased activity in the fiber space reflects growing consumer interest in higher broadband quality.

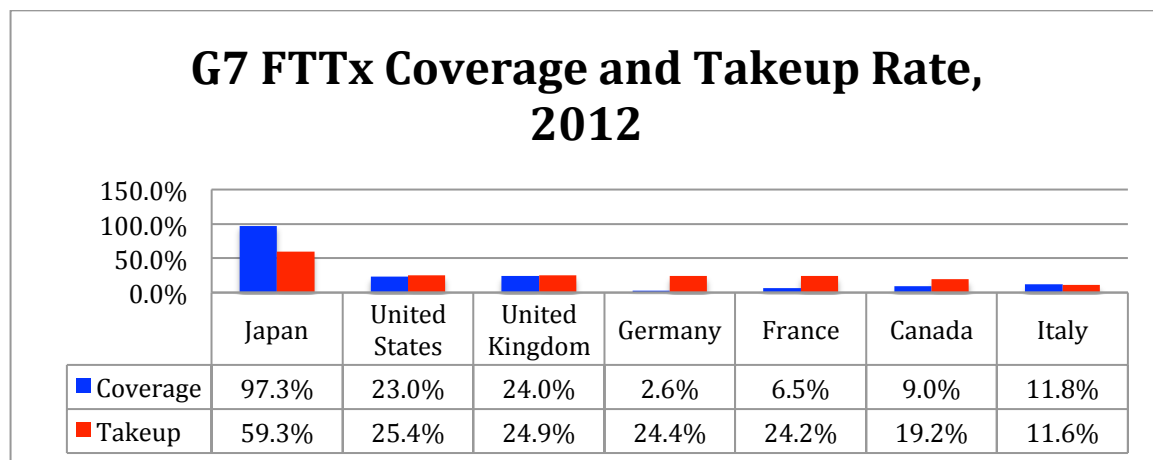


Figure 27. G7 FTTx Coverage and Takeup

Note: Takeup rate calculated on the basis of total FTTx subscriptions divided by total households with FTTx coverage. UK figures include VDSL.

Sources: OECD, “OECD Broadband Portal”; Ministry of Internal Affairs and Communications, *White Paper 2013: Information and Communications in Japan*; World Bank, “Population (Total),” 2014; NTIA and FCC, “Broadband Availability in Urban vs. Rural Areas”; NationMaster, “Average Size of Households”; and Point Topic, *Broadband Coverage in Europe in 2012*.

Wireless Subscription Rate

Pew also reports additional usage beyond those who use wired connections: “As of January 2014, 87 percent of American adults use the Internet.”⁴¹ Many Americans use the Internet from mobile devices or at work or school, so it may no longer be reasonable to measure subscription rates

strictly on wired networks. Bank of America/Merrill Lynch's (BAML) Global Wireless Matrix shows that smartphone adoption has already reached 50 percent of the population in the US and UK, and has reached significant mass in the rest of the G7 (Figure 28).

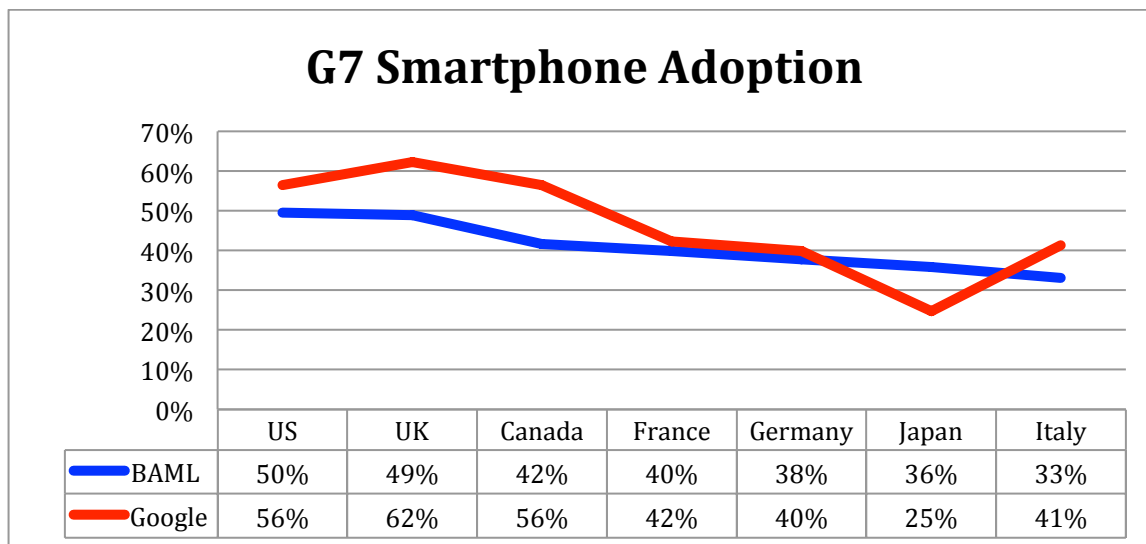


Figure 28. G7 Smartphone Adoption

Sources: Bank of America/Merrill Lynch, "Global Wireless Matrix 4Q13," January 8, 2014; and Google, "Our Mobile Planet."

Other sources are generally similar to Global Wireless Matrix data with respect to smartphone adoption but show significant differences in some details, especially with respect to Japan. Our Mobile Planet by Google shows very low smartphone adoption in Japan, which is hard to reconcile with estimates of mobile data usage, but because mobile video streaming is very

OECD shows that most of the growth in broadband subscriptions in the G7 now takes place on mobile networks.

common in Japan, the figures can be reconciled. Cisco estimates that national mobile data usage is heaviest in Japan—50 percent higher than the US on a population-adjusted basis. Consequently, the external evidence suggests the BAML estimate is more accurate, but Japan is a heavy user of mobile video. Pew Research estimates 56 percent smartphone adoption by US adults, in line with Google's estimate.⁴²

OECD shows that most of the growth in broadband subscriptions in the G7 now takes place on mobile networks (Figure 29). In the US, mobile broadband subscriptions were up 13.1 percent in 2013, while wired subscriptions were up only 3.7 percent.

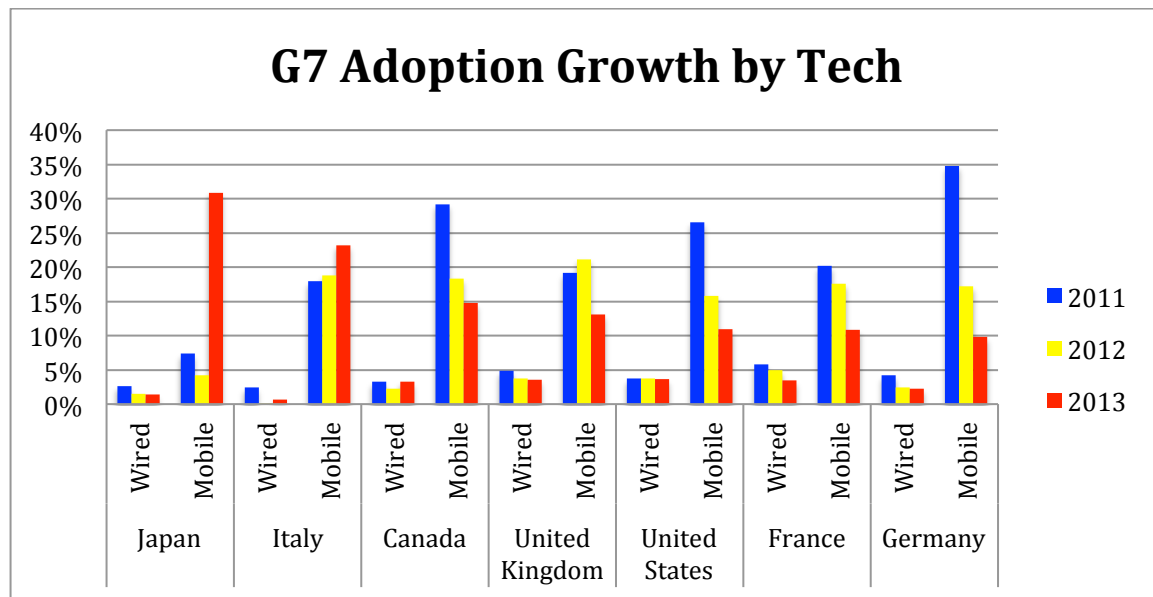


Figure 29. G7 Broadband Adoption Growth by Technology
Source: OECD, "OECD Broadband Portal."

The gap between mobile and wired growth rates is even more dramatic in Italy and Japan, where wired growth rates are less than 2 percent but mobile growth rates are 23 and 31 percent, respectively (Figure 30).

Mobile broadband subscription growth in Japan, Italy, and some other countries reflects a new kind of cord cutting, where young people are dropping wired broadband subscriptions in favor of advanced mobile broadband. This is an especially strong trend in East Asia, where wired networks are extremely fast but mobile networks are fast enough to meet a wide range of consumer needs. Informa analyst Tony Brown explains the dynamics:

Although the fact remains that wireless networks—even the greatly hyped newcomer LTE—can't carry the weight of demand for bandwidth from subscribers, there is now serious evidence emerging that the arrival of high-speed LTE networks coupled with the Smartphone and Tablet boom is creating serious problems for FTTH operators in some markets.

The best example of this is coming from Japan where fixed-broadband giants NTT East and NTT West have been forced to slash their FTTH prices for new subscribers by an eye-watering 34 percent from ¥5,460 (US\$66.70) to ¥3,600 per month to try and re-ignite their subscriber growth and stop the outflow of subscribers to cheaper LTE mobile broadband services.⁴³

While wired subscriber growth has slowed in Japan and Italy, it remains positive despite declining populations in both nations.⁴⁴

		2010	2011	2012	2013
Japan	Wired	7.50%	2.70%	1.50%	1.40%
	Mobile	3.20%	7.40%	4.20%	30.90%
Italy	Wired	7.80%	2.40%	0.10%	0.60%
	Mobile	94.80%	17.90%	18.80%	23.20%
Canada	Wired	3.80%	3.30%	2.30%	3.30%
	Mobile	ND*	29.20%	18.30%	14.70%
United Kingdom	Wired	6.00%	4.90%	3.70%	3.60%
	Mobile	44.70%	19.20%	21.20%	13.10%
United States	Wired	4.80%	3.70%	3.70%	3.70%
	Mobile	32.10%	26.60%	15.80%	11.00%
France	Wired	6.90%	5.80%	4.90%	3.40%
	Mobile	31.30%	20.20%	17.60%	10.90%
Germany	Wired	4.80%	4.20%	2.50%	2.30%
	Mobile	ND**	34.70%	17.20%	9.80%

Figure 30. G7 Broadband Adoption Growth by Technology, Details

Notes: *Canada increased from 0.9 percent to 30.4 percent from 2009 to 2010. **Germany increased from 0.1 percent to 26 percent from 2009 to 2010.

Source: OECD, “OECD Broadband Portal.”

Subscription Rate by Age Group

In the United States, subscription rates vary by age group, with seniors much more reluctant to use the Internet—and other forms of technology—than younger people (Figure 31). Within the senior category itself, older seniors are more technology-averse than younger ones (Figure 32). Similarly, seniors have low rates of computer ownership and a larger gap between computer ownership and Internet use than younger people (Figure 33).

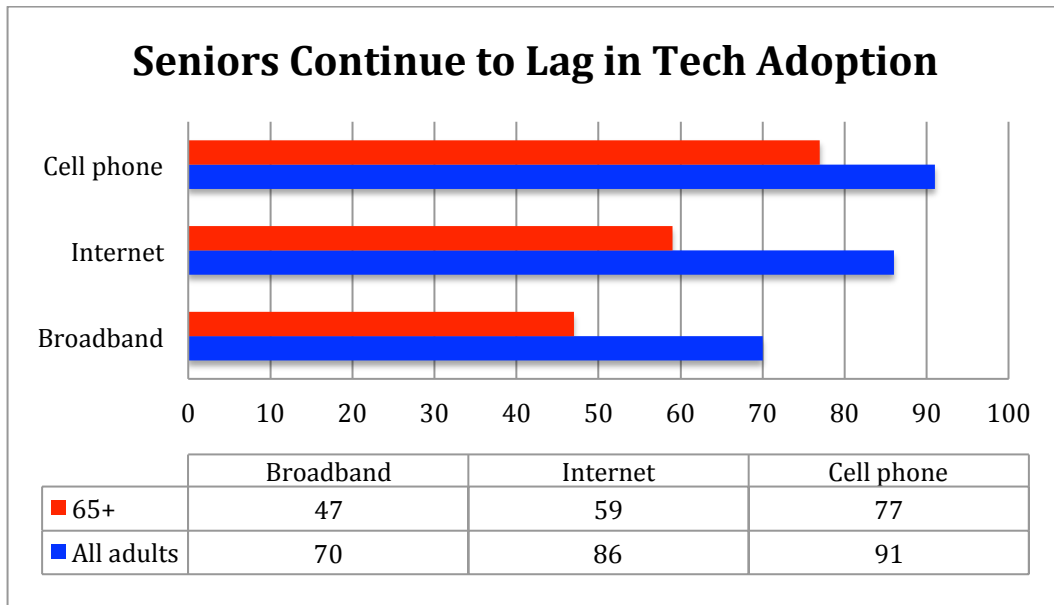


Figure 31. Seniors Continue to Lag in Tech Adoption

Source: Pew Research Center's Internet & American Life Project, "Usage and Adoption," April 2014.

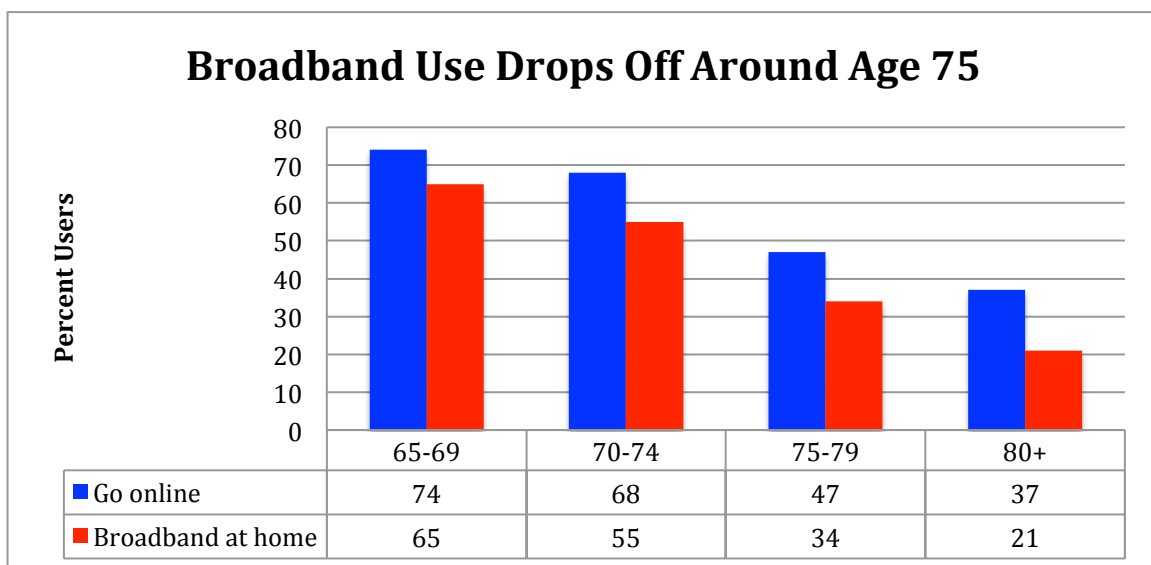


Figure 32. Internet and Broadband Use by Senior Age Groups

Source: Pew Research Center's Internet & American Life Project, "Usage and Adoption," April 2014.

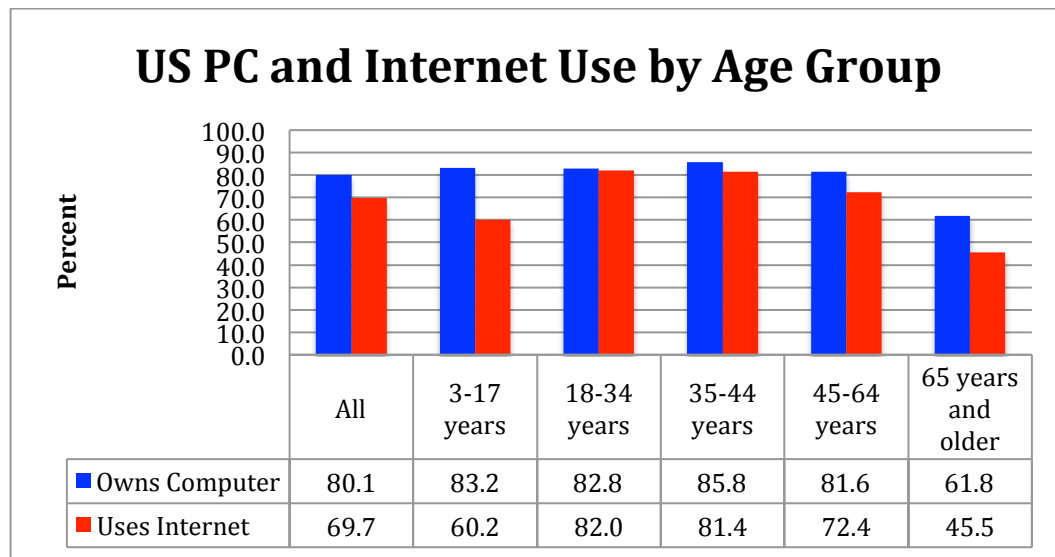


Figure 33. US PC and Internet Use by Age Group

Source: Thom File, *Computer and Internet Use in the United States, "Population Characteristics"* (US Census Bureau, May 2013).

The low rate of Internet use by seniors who own computers shows that the reluctance to go online is not simply a matter of low rates of computer ownership, as some have maintained. It also suggests that outreach programs aimed at the senior population are likely to increase seniors' rate of Internet use even when not combined with programs to subsidize computer ownership. With the rise of the tablet and the smartphone, computers are no longer Internet prerequisites; the primary factor is interest.

Policy Issues

The social benefits of broadband depend on broad adoption. Until nearly all Americans use broadband services, paper forms and telephone interactions cannot be fully replaced by less expensive and more valuable broadband modalities. Consequently, broadband users have a vested interest in broadband use by others. Broadband service providers and Internet businesses also have interests in broader adoption, as the nonadopter population represents additional revenue opportunities at relatively low cost.

The social benefits of broadband depend on broad adoption.

For this reason, a number of firms, from broadband service providers such as Comcast to web services firms such as Facebook, have developed initiatives to encourage broader adoption of the Internet both in the US and in the rest of the world. Other governments have also been active in promoting Internet use through outreach programs; these have been particularly successful in Korea and Singapore, for example.⁴⁵

Public/private partnerships are a useful policy avenue to pursue for stimulating Internet use, as government and the private sector share the benefits of broader adoption. Broadband deployment—at basic performance levels—is a solved problem in the US at this point, so it is reasonable to redirect at least some Universal Service program funds toward demand creation programs. However, the private and nonprofit sectors are best equipped to manage adoption programs. Researcher John Horrigan finds that members of social groups in which Internet use is common value it most highly.⁴⁶

Broadband Performance

Measuring network performance is difficult because a number of nonnetwork factors always intrude in any system of network measurement. The Internet is an “end-to-end” system in which a key component—the TCP module—runs on the end user’s computer outside the control of the network operator. The performance of end-user computers affects the test scores obtained by TCP-level tests such as Ookla Speedtest and Akamai.

The other end of a performance test is either a test server located at some location on the Internet or a commercial server in an unknown condition of load and capacity. Although the path to a test server can be controlled, it does not reflect the performance that users experience. But the

FCC measurement of web page load time shows that the web server and browser account for 75 percent of load time when users are on a 50 Mbps connection.

capacity of web servers, another issue outside the control of the network operator, dominates experienced performance. FCC measurement of web page load time shows that the web server and browser account for 75 percent of load time when users are on a 50 Mbps connection. Other web page load tests, such as Akamai’s, report load times five times higher than the FCC measurements.

The Internet is a mesh of millions of paths between clients and servers, each of which exhibits different capacity, delay, and loss characteristics. The diversity of these paths is not easily captured; hence, broadband testing tends to be done by specialized test devices such as the SamKnows “White Box,” which connects directly to the user’s cable modem or DSL access device. The data recorded by such devices are influenced by their distribution, however. As in any other kind of polling, it is critical to survey a representative sample of the population, but the FCC admits that SamKnows White Box users often upgrade their service tiers from year to year and therefore are not as representative of the overall population as they might be.

Sampling is an even more serious problem with crowdsourced systems such as OpenSignal and Ookla Speedtest. These systems are entirely self-selected, so they are no more representative than website polls of political questions. In the Ookla Net Index (Net Index is a compilation of Speedtest data) sample data, no correlation exists between the number of tests run in each nation and the Internet user population—70 tests from Canada versus seven for Germany, for example. TCP performance is influenced heavily by distance between client and server—this is the reason for CDNs—but the sample data show distances as short as eight-tenths of a mile and as long as 8,000 miles. The Ookla tests are regarded as reasonably reliable for each instance of testing, allowing for end-system performance variations, but their lack of a representative sample population undermines their validity. OpenSignal, a system that purports to measure mobile network performance, suffers from the same limitations.

Consequently, no single network performance test is definitive, and it is necessary to synthesize results to develop a useful picture, in much the same way that Nate Silver synthesizes political polls.

The performance measure of greatest significance is web page load time, but data on this dimension are not yet as well developed as they should be, but we can begin to draw useful conclusions already.

Application Requirements

Before we delve into the arcana of broadband performance measurement, it is worthwhile to frame the subject in the proper context. Broadband performance is often an issue of national pride or a stalking horse for a desired regulatory outcome, such as nationalization. It is easy to recognize outcome-driven rhetoric in discussions of network performance: when speakers make vague or anecdotal claims about “other countries” that are alleged to be doing wonderful things that they say their own country should mimic, something may well be amiss. No prizes are given to the fastest or even the cheapest networks; the goal of network performance is adequate access to applications.

If a nation’s networks are fast, cheap, reliable, and pervasive enough to enable citizens to enjoy the full panoply of applications, citizens win. If networks are even faster than they need to be, there is no additional benefit, but there may be one for less expensive networks than ones that push the boundaries of affordability. A number of studies have attempted to quantify application requirements, but they tend to be flawed in similar ways to the studies that attempt to quantify broadband’s contribution to GDP; both types of studies tend to be outcome-driven.

For example, Saunders, McClure, and Mandel emphasize download times for entertainment media files (Figure 34).

Media type and file size		Network download speed			
Type	Size	4 Mbps	10 Mbps	20 Mbps	50 Mbps
Four-minute song	4 MBs	7.6 seconds	3 seconds	1.5 seconds	0.6 seconds
Five-minute video	30 MBs	57 seconds	22.9 seconds	11.4 seconds	4.5 seconds
Nine-hour audio book	110 MBs	3.4 minutes	1.4 minutes	42 seconds	17 seconds
35-minute TV show	200 MBs	6.4 minutes	2.5 minutes	1.27 minutes	30 seconds
45-minute HD TV show	600 MBs	19 minutes	7.6 minutes	3.8 minutes	1.5 minutes
Two-hour movie	1.5 GBs	47.6 minutes	19 minutes	9.5 minutes	3.8 minutes
Two-hour HD movie	4.5 GBs	2.3 hours	57 minutes	28.6 minutes	11.4 minutes

Figure 34. Download Times for Entertainment Media Files

Source: Jeff D. Saunders, Charles R. McClure, and Lauren H. Mandel, “Broadband Applications: Categories, Requirements, and Future Frameworks,” *First Monday* 17, no. 11 (November 5, 2012).

The authors seek to connect file download times to streaming media services:

Downloading movies and TV shows is big business for companies like Netflix, Hulu, and Apple. However, all of these companies perform a balancing act between the quality of the video content provided and the amount of bandwidth consumed by the user (Moon, 2012). These companies are concerned with bandwidth consumption due to some Internet service providers (ISPs) placing data caps on customers that consume more than a certain data amount each month.⁴⁷

But streaming media services do not download entire files before they begin to play them out; they simply fill a small buffer and then continue to download as they play. The 9.5 minutes it may take to download a two-hour movie at 20 Mbps is utterly unimportant; with Netflix, the movie begins to play in less than five seconds. There is a certainly a case to be made for networks that permit rapid movie playout from the memory on the playback machine, but movie playout needs are satisfied by an honest 10 Mbps connection every bit as well as they would be by a 100 Mbps connection permitting two-minute file downloads.⁴⁸

Web page load times are dominated by server performance rather than network constraints at broadband connection speeds greater than a few megabits per second.

Similarly, common interpersonal communications such as instant messaging, Twitter, and email are perfectly usable on dial-up connections and do not provide an argument for broadband. Web surfing is different, as it clearly does require broadband connections. Traditional human factors research suggests that web pages need to load in five seconds or less to be considered usable.⁴⁹

More recent thinking suggests that users prefer commerce and entertainment sites that load quickly, and an entire content delivery network industry has developed around web

acceleration to enable this. But CDNs reduce the load times of web pages not by making more network bandwidth available to the user, but by reducing distance, circumventing TCP design defects, and increasing server performance with faster CPUs and storage.⁵⁰ Web page load times are dominated by server performance rather than network constraints at broadband connection speeds greater than a few megabits per second in any case, as evident when I discuss web page load times later in this paper.

Some applications have hard performance limits, however: immersive video conferencing (like Cisco Telepresence) requires an actual 15 Mbps connection at 1080p, plus additional headroom to recover from delays common on the public Internet at subsecond intervals.⁵¹ The routine use of high-definition medical images might well require 300 Mbps to transfer images in less than five seconds if they have the characteristics described in the Saunders et al., paper, but this would be a commercial, not residential, network connection.⁵² Looking into the future, the only applications that would require capacities greater than 100 Mbps and less than 1 Gbps are holographic conferencing and multiparty video conference hosting; simple participation in a multiparty video call is no more demanding than Cisco Telepresence.

The FCC's current proposed benchmark for adequate broadband capacity is 10 Mbps for all locations, urban and rural; if we double that value to account for network load variations caused by wired network sharing, we can safely assume that no meaningful current application is left behind.⁵³ Consequently, it is reasonable to assume that 20 Mbps is the threshold for desktop applications and 10 Mbps of mobile bandwidth is the threshold for smartphone applications. FCC Chairman Tom Wheeler's claim that 25 Mbps is "table stakes" for emerging applications is aspirational; current applications do not stress the capacity of current networks.⁵⁴

Wired Network Performance

Wired network performance is easier to measure than wireless, but all forms of network capacity measurement are difficult, as noted. Wired network tests tend to be more reproducible and less device-dependent than mobile tests, but each suite measures a different thing. Now, I will examine the eccentricities of each method.

Akamai Typical Broadband Speeds and Adoption. Akamai's quarterly *State of the Internet Report*, which has measured broadband performance and adoption since mid-2007, is one of the most valuable tools for measuring broadband deployment and adoption trends.⁵⁵ The Akamai data focus on the observed performance of actual networks, so they see a different part of the broadband ecosystem than the one surveyed by artificial speed tests such as SamKnows and Ookla. Akamai's data allow us to see trends in the deployment and use of networks typical of both the Basic and the Advanced Broadband stages.

Since the third quarter of 2007, Akamai has collected data on the percentage of TCP connections transferring data at 4 Mbps or higher; this measurement is termed "broadband adoption" (see Figure 35). Akamai's data are often reported in the press as measurements of network

performance, but this is true only when they are used carefully. Akamai measures TCP connections rather than gross network capacity, and it does so under real-world conditions. In most Internet uses, multiple TCP connections run in parallel, so a measure of one does not stand in for network capacity.

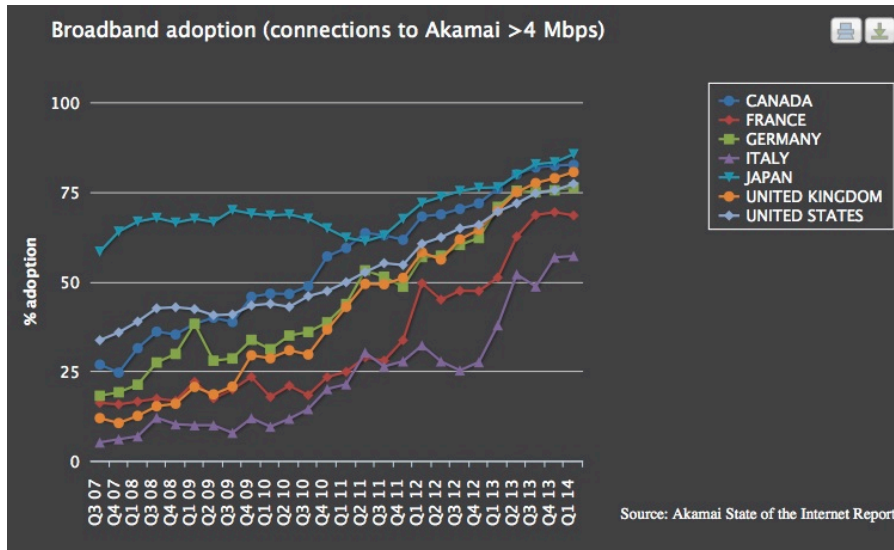


Figure 35. Medium-Capacity Broadband Prevalence, 2007–14

Source: Akamai *State of the Internet Report*, www.akamai.com/stateoftheinternet.

Akamai’s “Average Peak Connection Speed” (APCS) is a fair proxy of network capacity, but its more commonly cited “Average Connection Speed” (ACS) is not. ACS is taken in shared capacity settings, one in which multiple TCP connections run in parallel, taking bandwidth away from one another in at least three different ways:

1. Such applications as web browsing use 4–8 TCP connections at the same time, so each TCP connection only represents a fraction of the network’s capacity. The average web page requires 37 TCP connections, so most downloads take place in parallel.⁵⁶
2. When multiple users share a common broadband connection—the typical case in homes, schools, and businesses—each user can consume only a fraction of the overall capacity of the connection when other users are active.
3. Some applications—such as Netflix video streaming—self-limit TCP stream capacity to conserve server resources.

Akamai does not aggregate all TCP connections in use on a given IP address at the same time because it cannot see all of them. Akamai’s ACS simply averages the capacities of all the TCP connections it sees.

Consequently, achieving an average TCP connection speed of 4 Mbps or more requires a peak network capacity of 15 Mbps or more as these two terms are generally in a 1:4 ratio. Four Mbps is the threshold to the most common data applications the Internet has to offer in the most common sharing scenarios.

Figure 36 shows the prevalence of connections with average measured capacities greater than 4 Mbps in the overall mix of connections measured by Akamai as basic broadband over the most recent year. This graph is remarkable in two respects: it is the only graph of G7 broadband that shows the US ranking lower than second, and it is the only graph that fails to show Japan substantially ahead of the second-place nation; in fact, Canada and Japan are in a virtual dead

heat, separated by less than one percentage point. In light of the Japan's heavy spending for high-capacity broadband, this may be the most expensive percentage point in the entire data set.

Reports from the most recent quarter (Q1 2014) and the year-earlier quarter show substantial progress in Italy, France, the UK, and Japan (Figure 36).

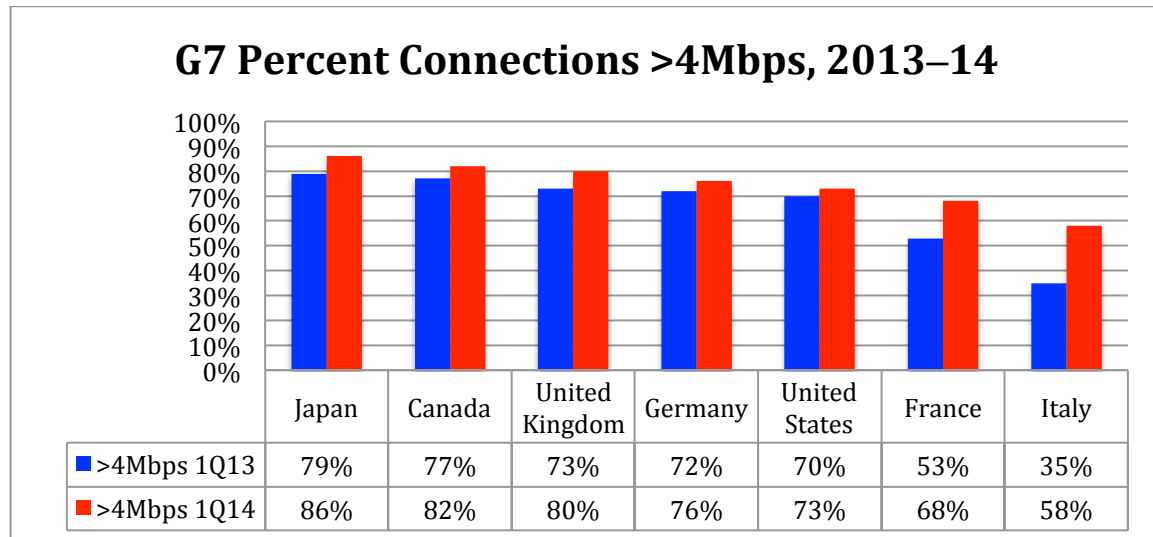


Figure 36. G7 Percent of Connections Faster Than 4 Mbps, Q1 2013–Q1 2014

Source: Akamai State of the Internet Report, www.akamai.com/stateoftheinternet.

Akamai High Broadband Speeds and Adoption. Akamai has also collected data on the percentage of TCP connections transferring data at 10 Mbps or higher; this measurement is termed “high-speed broadband adoption.” TCP does not always transfer data at the full capacity of the underlying broadband network, for reasons I have cited, and because short-lived TCP connections do not graduate from the initial state, performance-impaired “slow start,” to full capacity before they are abandoned.

Consequently, achieving an average TCP connection speed of 10 Mbps or more requires a peak network capacity of 40 Mbps or more. Ten Mbps of TCP ACS is, therefore, the threshold to the most demanding data applications the Internet has to offer in the most-intensely shared scenarios.

High-speed broadband adoption data follow a familiar pattern: Japan has the highest score; the US, UK, and Canada are next; and continental Europe lags behind. This pattern appears throughout G7 performance data (Figure 37).

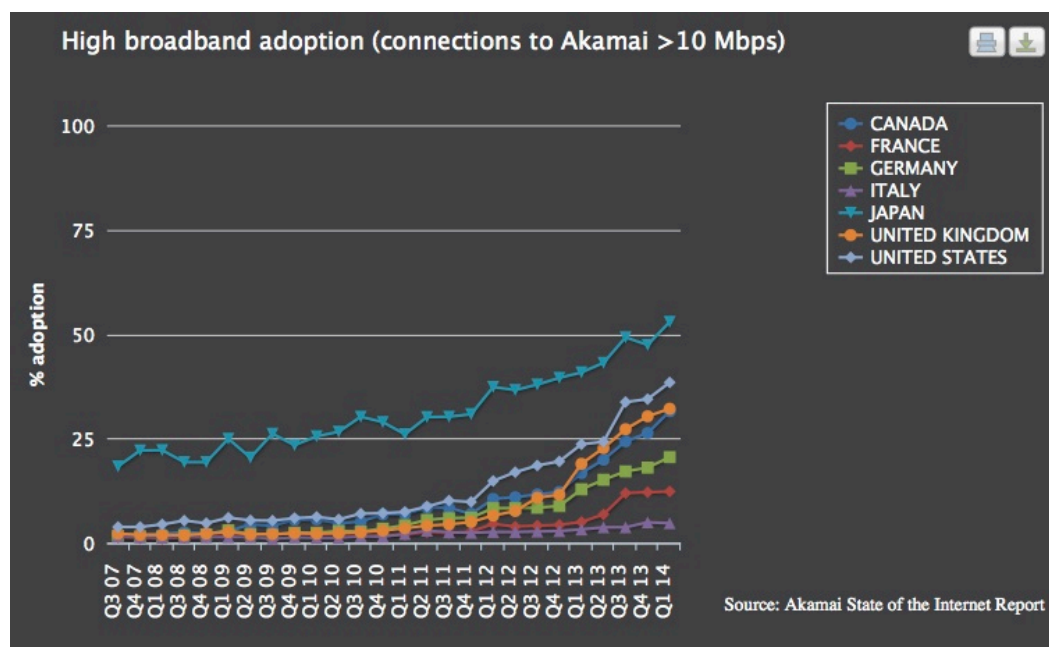


Figure 37. High-Capacity Broadband Prevalence, 2007–14

Source: Akamai State of the Internet Report, www.akamai.com/stateoftheinternet.

In the most recent quarter, no nation showed more than 50 percent of its TCP connections running consistently faster than 10 Mbps, but all showed annual improvement (Figure 38). France made the most progress, 146 percent, but it remains second to last overall at 12.3 percent.

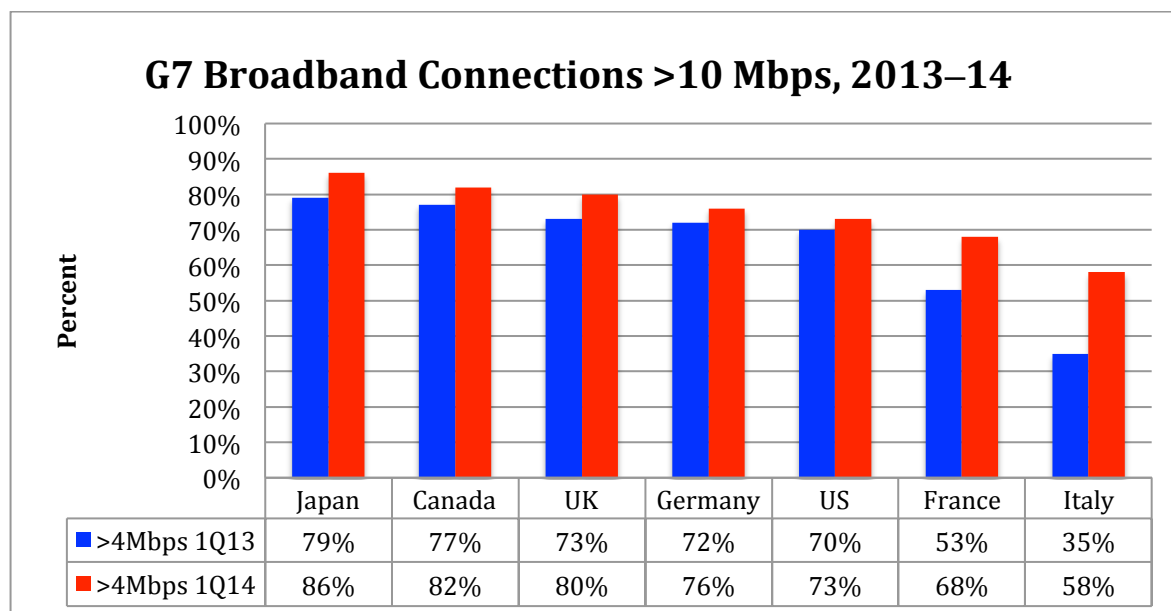


Figure 38. G7 Percent of Connections Faster Than 10 Mbps, Q1 2013–Q1 2014

Source: Akamai State of the Internet Report, www.akamai.com/stateoftheinternet.

All nations made improvements in Q1 2014 over the previous quarter, which is unusual. In the preceding quarter, Japan showed a decline over the previous quarter. Occasional declining scores are consistent with broadband dynamics: as user populations grow, usage becomes more intense,

or applications are revised to consume more resources, performance will often degrade until providers add capacity to their networks at bottleneck locations. Upgrades are not always made on time and to the right locations, so a certain amount of slippage is inevitable.

In other words, the sawtooth pattern often seen in quarter-to-quarter historical network performance data is caused by usage catching up to capacity and capacity then increasing. Capacity bottlenecks do not generally appear in the last mile of cable and fiber networks; more

commonly, they are found in aggregation points.

The alternation of periods of advance and decline is a fundamental dynamic of broadband networks.

Consequently, Japan's seven upgrades and the US's five since 2007 have resulted only rarely in higher advertised speeds.

The alternation of periods of advance and decline is a fundamental dynamic of broadband networks that has not been acknowledged in policy studies; providers increase capacity in response to utilization, but every increase is

effective for only a limited time. Nations seldom decline in speed over long periods, but policy models must enable carriers to respond to increased load.

Akamai Average Network Capacity Measurement. As previously noted, Akamai measures two capacity averages, APCS and ACS, both of which are commonly reported in a misleading manner.⁵⁷ APCS is the mean of the highest TCP connection speeds seen on all the IP addresses in the nation or region, while ACS is the mean of all TCP connections.

These averages differ by a ratio of 4:1, which indicates that the typical ACS measurement scenario involves some mix of IP address sharing, four or more active TCP connections per user (a characteristic of web browsing), a rate-limited service such as video streaming running at one-fourth the network's capacity, TCP connections in the "slow start" impairment condition, or upstream network congestion.⁵⁸

Some commenters have asserted that the discrepancy between average TCP connection speeds and average peak TCP connection speeds always comes down to network congestion,⁵⁹ but this claim is not consistent with measurements of advertised versus actual speeds in the US⁶⁰ and in Europe.⁶¹

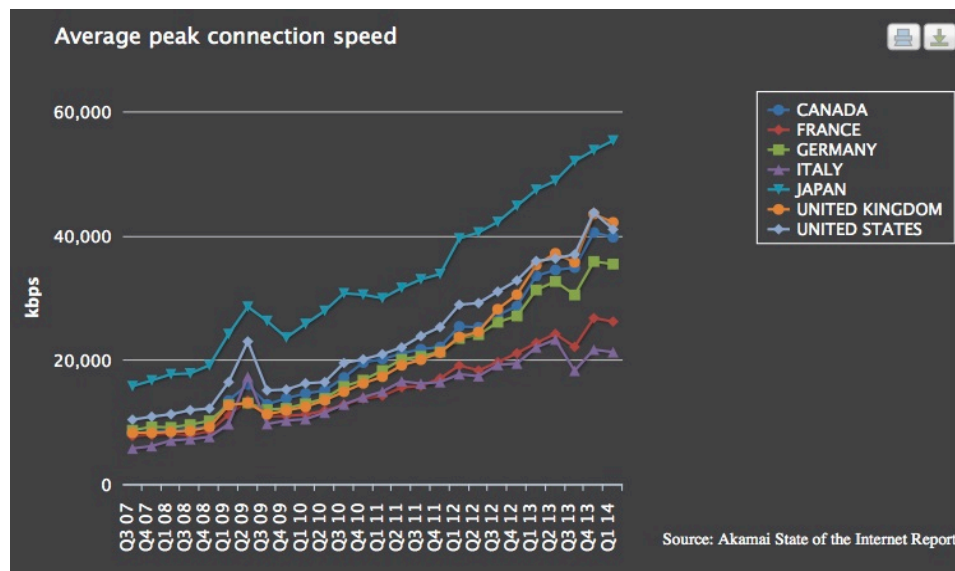


Figure 39. Network Capacity in G7 Nations, 2007–14

Source: Akamai *State of the Internet Report*, www.akamai.com/stateoftheinternet.

If we want to know how much capacity a nation's broadband networks provide, on average, the most appropriate measurement is Akamai's APCS. It tells us what the capacity of the underlying network is, independent of states of load and parallel transfers by the end user. For the most recent two quarters reported, Q4 2013 and Q1 2014, APCS places the United States at 43.7 and 40.6 Mbps, respectively, behind Japan and slightly behind the UK's 43.5 and 42.2 Mbps (Figure 40).⁶² Continental Europe brings up the rear, with capacities as low as 21.4 Mbps in Italy.

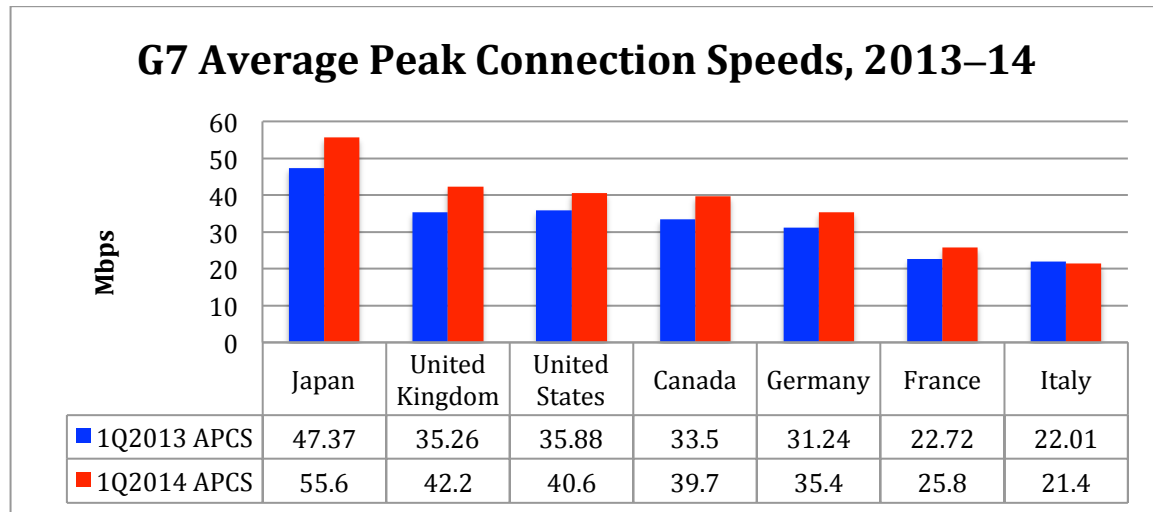


Figure 40. G7 Broadband Capacities, Q1 2013 and Q1 2014

Source: Akamai *State of the Internet Report*, www.akamai.com/stateoftheinternet.

ACS is helpful in calculating average web page load time and the download time of large files; it would not be particularly helpful in connection with video streaming since all media streaming applications are self-limited; on America's gigabit networks, such as Google Fiber, Netflix streams at less than 4 Mbps, for example.⁶³ Consequently, Akamai excludes self-limited streams from its measurements.

Ookla Wired Network Speed Tests. Unlike Akamai, which measures a representative sample of Internet users while they are engaged in their normal activities, Net Index from Ookla is a crowdsourced test that measures only the performance of networks and systems selected by particular users. Speed tests are typically run to troubleshoot problems and to verify upgrades; many users test the same path several times in quick succession, others test only once, but most users do not run the test at all.

Considerable discrepancies exist between Akamai's APCS—the metric that best approximates network capacity—and the Ookla results. Akamai ranks Japan at the top of the G7 in download speed, which is the expected result given the prevalence of 100 Mbps and 1,000 Mbps connections in Japan. It ranks France sixth, which is also consistent with the nature of that nation's infrastructure; France is predominately a first-generation DSL nation, with very low penetration of VDSL, DOCSIS, and FTTH. But Ookla inexplicably ranks France at the top of the G7 and Japan in fifth place (Figure 41). Akamai ranks the UK, the US, and Canada in a virtual tie for second place, but Ookla ranks Canada in sixth place. Both tests agree on ranking the UK second, the US third, and Italy last, however.

Ookla reports measurements on a monthly basis, and its data vary considerably from month to month; Akamai releases measurements once a quarter, and there is generally very little variance

in their data. (Some quarters have been anomalous, such as Q2 2009, but uniformly so across the entire set of nations.)

The best way to use Ookla data is for its intended purpose—to isolate changes on a given connection,; its validity across nations is dubious because of sampling issues. It is noteworthy that the most aggressive critics of broadband in America rely on Ookla data to support their “falling dangerously behind” claims.⁶⁴ These critics are victims of bad data, for the most part.

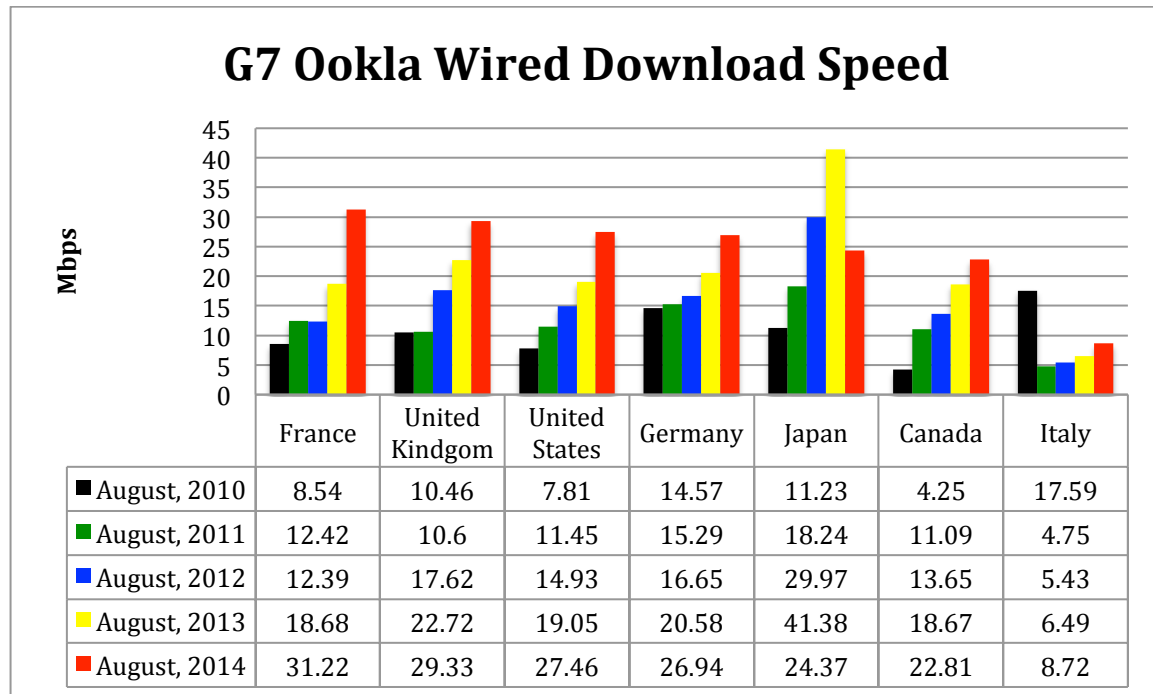


Figure 41. Ookla Survey of G7 Wired Network Speed
 Source: Net Index from Ookla, “Download Speed by Country.”

Resolving Wired Measurement Discrepancies. Because of the discrepancy between Ookla and the known characteristics of broadband infrastructure, it is best to discard Ookla’s reports of national broadband speed altogether. Not only is Akamai consistent with expected speeds, but it is also consistent with speeds measured by SamKnows. Hence, Akamai and SamKnows together give us a consistent picture represented by two independent measurements. As much as possible, we should examine at least two consistent sources of data before drawing any conclusions; the scientific method requires reproducible measurements.

Mobile Network Performance

Mobile network performance is even harder to measure than wired network performance. Mobile networks depend on the same highly variable wired infrastructure that exhibits extremes of congestion and server overload, and they also feature an additional set of variables related to radio interference, signal strength variations because of distance from the cell tower, and environmental barriers to a clear signal.

As if these factors are not complicated enough, handheld devices also have slower processors than desktop and laptop computers, and many forms of testing reflect as much on processor power as on network capacity. Dedicated test devices like the SamKnows White Box are not currently used for mobile network testing, so the accuracy and reproducibility of mobile network

tests is questionable. All mobile network test data sets show a much larger range of variations in test data points than wired tests do. This is reflected in the peak-to-average ratio in tests such as the Akamai/Ericsson test suite.

First movers are penalized in mobile speed tests.

Akamai Measurements of Actual Mobile Broadband Speeds. In the past, Akamai reported mobile speeds on a network-by-network basis, but beginning with the Q1 2014 report, Akamai's mobile measurements are aggregated at the country level and combined with a high-speed adoption figure reflecting the percentage of connections measured at 4 Mbps or higher. This speed indicates

3.9G/4G mobile devices operating at an underlying link rate of at least 8 Mbps because of the way the streams are measured. (See explanation of Akamai's test methodology in the "Wired Network Performance" section.)

First movers are penalized in mobile speed tests. The US now shows pedestrian mobile speeds, ranking next to last in the G7, largely because it was the first nation to adopt LTE (Figure 42). This means the US has more LTE users in proportion to the overall mobile user population, older and slower handsets, and greater contention for spectrum. The Akamai test does not reflect Wi-Fi usage, which further penalizes the US.

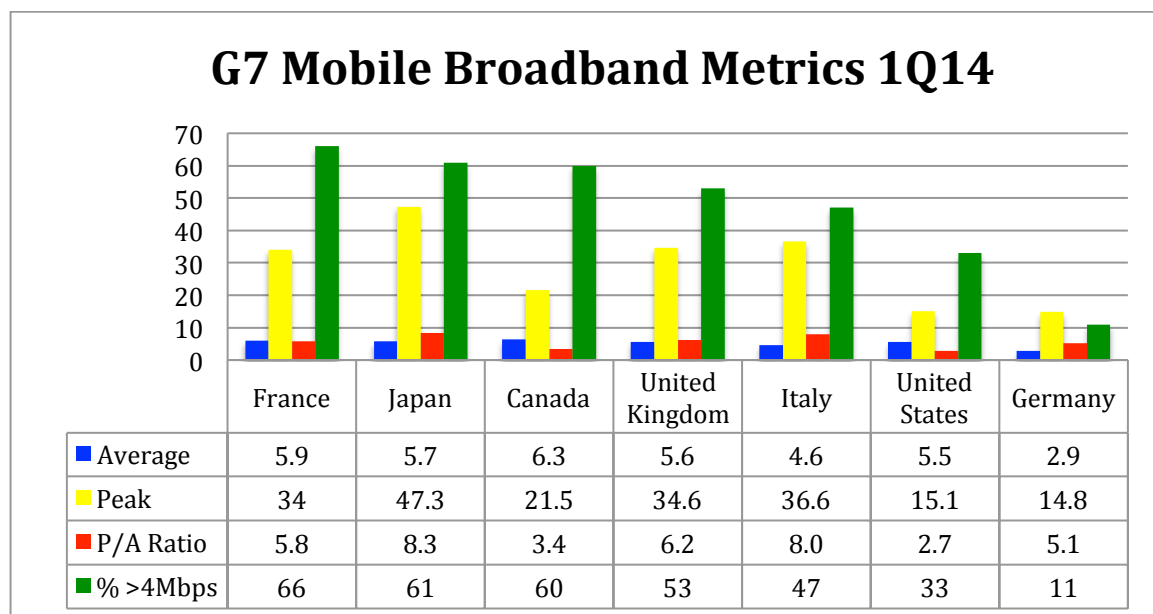


Figure 42. G7 Mobile Broadband Speed, Q1 2014

Source: Akamai *State of the Internet Report*, www.akamai.com/stateoftheinternet.

It is interesting that one nation with very poor wired capacity, France, scores very well on mobile capacity, while other nations poorly connected by wire, Italy and Germany, are also poorly connected by mobile. This discontinuity may be a clue that policy differences are afoot in continental Europe, but it could also be a testing artifact. Such discontinuities are one reason that it is useful to examine test data carefully.

The poor showing of the US in mobile download speed also indicates that our networks need an upgrade to the next generation of mobile, LTE Advanced. This upgrade is indeed in progress: the fastest mobile network in the US today is the recently upgraded T-Mobile system. Verizon is already rolling out an LTE Advanced system under the name "XLTE."⁶⁵ Sprint is rolling out "Spark," an LTE Advanced system promising speeds up to 180 Mbps by 2015.⁶⁶ AT&T is

operating LTE Advanced in Chicago and other markets already, with a national rollout to follow shortly.⁶⁷ Consequently, the test scores should show some major differences a year from now.

Ookla Mobile Network Speed Survey. Ookla also conducts mobile network testing using the same crowdsourced methodology it uses for its wired tests, and with the same limitations. Like Akamai, it shows high speeds in France in the most recent test period and low speeds in Italy (Figure 43). Speed in France has undergone a major leap forward in the first year of LTE: France has risen from 6.7 Mbps to 16.23 Mbps, an impressive feat that can only indicate a major network upgrade. All G7 nations advanced to some extent, although Canada's improvement was extremely slight, less than 500 Kbps. Italy trails its G7 comrades but doubled its score nonetheless; this probably indicates a major upgrade in the early stages of deployment.

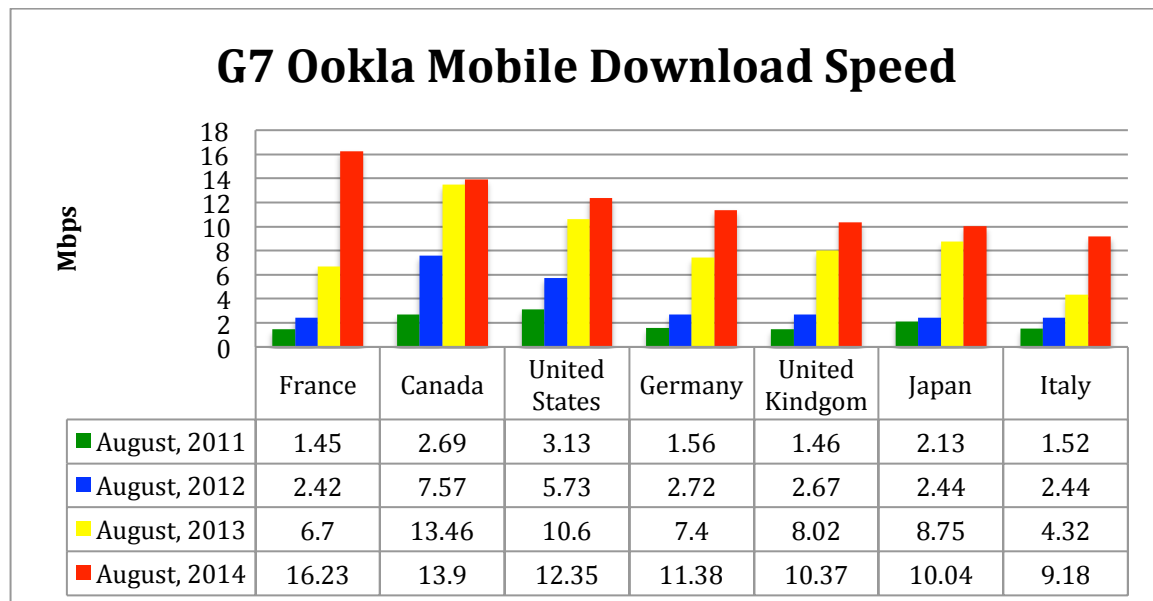


Figure 43. G7 Ookla Mobile Download Speed
Source: Net Index from Ookla, "Download Speed by Country."

Ookla shows the US, Germany, and the UK clustered close together in the middle of the performance range. All nations show average speeds in the Ookla test of 9 Mbps or more, which is sufficient for users to enjoy the full benefits of the mobile experience. The ratio of fastest to slowest speed in Ookla's look at G7 mobile is less than 2:1, not so large as to impact the user experience significantly.

OpenSignal LTE Speed and Coverage Survey. OpenSignal, a crowdsourced mobile measurement tool, has published two reports on LTE since February 2013. The most recent report shows coverage as well as speed, which is probably a more accurate and meaningful measure because coverage is less device dependent than is speed testing (Figure 44).⁶⁸

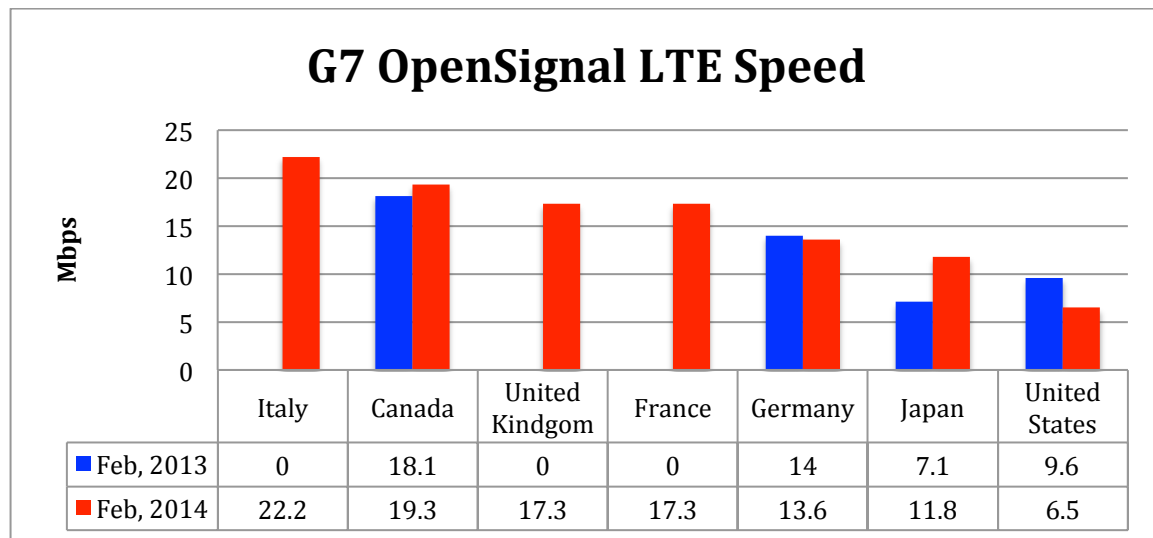


Figure 44. G7 OpenSignal LTE Speed Survey
Source: OpenSignal, *The State of LTE February 2014*.

OpenSignal's estimates of LTE download speeds diverge from Ookla's and Akamai's by a considerable degree, which shows the impact of test methodology and the self-selection of crowdsourced measurement.

Resolving Mobile Measurement Discrepancies. The average download speed of America's mobile broadband networks may be 5.5 Mbps (Akamai), 6.5 Mbps (OpenSignal), or 12.35 Mbps (Ookla). The discrepancy between the Akamai and Ookla measurement reflects some methodology; Akamai measures individual real-world data flows but does not aggregate them. Therefore, a web page that downloads at an overall rate of 40 Mbps will register as four flows of 10 Mbps in the Akamai system when four TCP connections are active at the same time, the normal state of affairs on broadband networks. But Ookla runs a test program that aggregates downloads through a single connection instead of simply observing data flows from real web pages.

Akamai measures average peak connection speed, the figure that best approximates network capacity, at 40.6 Mbps on US wired networks, a ratio of about 4:1 over the average connection speed of 10.5 Mbps Akamai measures for US wired networks. The ratio of peak to average Akamai measures for US mobile networks is smaller, 2.7:1. This is reasonable, given that mobile browsers are not as heavily parallel as wired ones.

The Akamai peak connection speed measurement for mobile networks in the US is reasonably close to the Ookla measurement at 15.1 versus 12.4 Mbps. Consequently, the actual average speed of US networks is probably somewhere between the Akamai peak and the Ookla measurement. But the discrepancies between these two tests are very large in other countries: nearly 5:1 for Japan, 4:1 for Italy, and 3.5:1 for the UK. Consequently, it appears that the most reasonable way to use mobile speed test scores is on the basis of the median of the three tests (Figure 45).

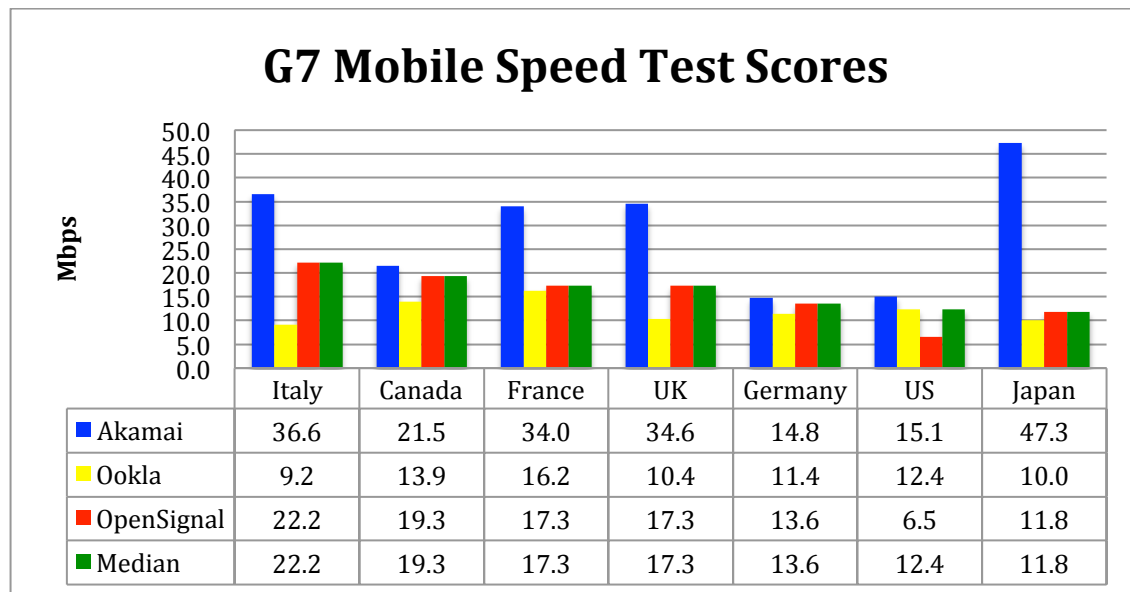


Figure 45. G7 Mobile Speed Test Scores

Sources: Akamai *State of the Internet Report*, www.akamai.com/stateoftheinternet; Net Index from Ookla, "Download Speed by Country"; and OpenSignal, *The State of LTE February 2014*.

Italy and Canada have the highest median scores, and the US and Japan have the lowest. This is probably an indication of how heavily the networks are used, as the US and Japan have the most broad adoption of the fastest network technology, 4G/LTE.

LTE Speed vs. Coverage

Although the OpenSignal data is not reliable as a measurement of speed across nations, it includes data on LTE coverage that are not found in other data sets: OpenSignal measures the percentage of time in which the device was able to access an LTE network in its native mode. This is an indication of the progress of the LTE buildout, as devices will fall back to 3G when an LTE signal cannot be found.

As we should expect, LTE coverage is most pervasive in the US and Japan, the first two nations in the G7 to deploy LTE at scale (Figure 46). The networks with the most pervasive LTE coverage in the G7 are KDDI in Japan and MetroPCS and Verizon in the US. The MetroPCS figure is somewhat misleading, as it converted its entire network to LTE and dropped support for older technologies.

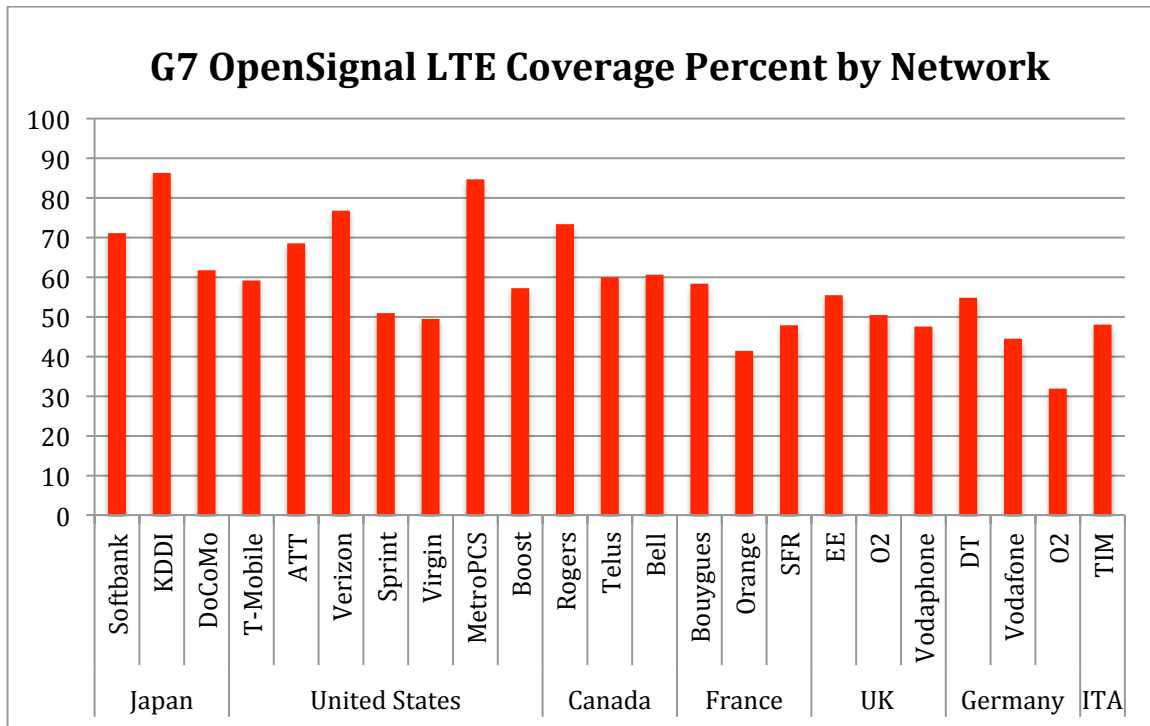


Figure 46. G7 OpenSignal LTE Coverage Percent by Network

Source: OpenSignal, *The State of LTE February 2014*.

Counterintuitively, LTE coverage does not correlate positively with speed in OpenSignal's estimation. KDDI ranks second in speed in Japan despite its superior coverage, Verizon ranks third in the US, and MetroPCS is next to last in the US with a dismal score of 2.4 Mbps (Figure 47). The MetroPCS score is easy to understand: the firm has very limited spectrum holdings and has merged with T-Mobile in the interest of spectrum aggregation. But KDDI and Verizon have extensive holdings and are most likely paying the price of being first movers. The highest speeds are generally found on relatively new deployments, and over time they decline until the next generational upgrade boosts them again. Consequently, the speed of almost any network is an inverse function of time since last upgrade, while coverage is a positive function of the same factor.

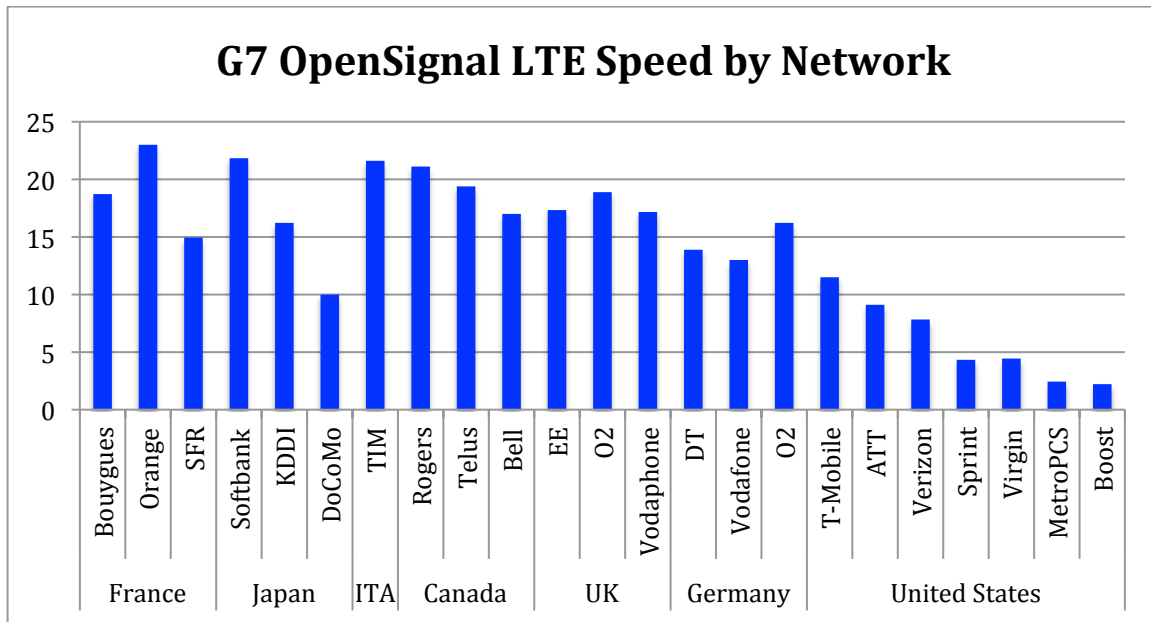


Figure 47. G7 OpenSignal LTE Speed by Network
Source: OpenSignal, *The State of LTE February 2014*.

Smoothing the data for speed and coverage across the entire set of LTE networks OpenSignal has mapped in the G7 shows this correlation: where coverage is low, speed is high, and vice versa. Consequently, it is prudent to examine both speed and coverage in tandem when passing judgment on the network quality in any nation.

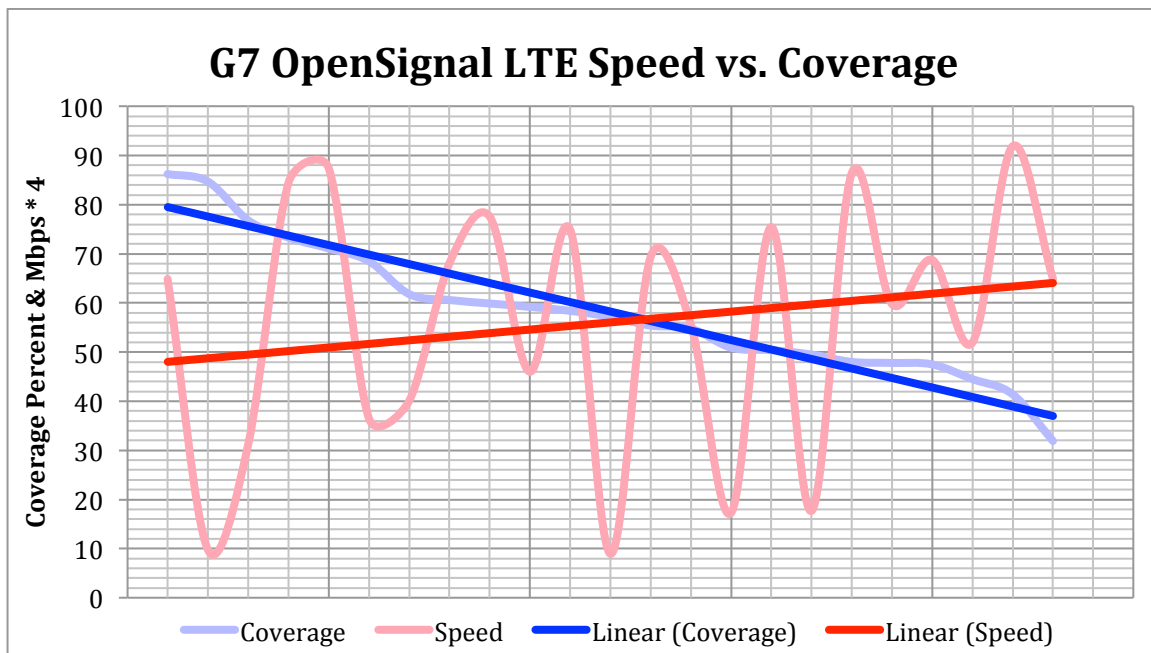


Figure 48. G7 OpenSignal LTE Speed as Function of Coverage
Source: OpenSignal, *The State of LTE February 2014*.

Browsing Speed

Speed tests are all well and good, but they do not tell us a great deal about the ways that we experience network services or about the utility that our networks have for day-to-day tasks and applications. In an attempt to bridge the gap between theory and practice, network testing is beginning to collect data on the actual speed of web page loading: both Akamai and SamKnows are making this effort. This measurement is at an early stage, but it has already produced interesting results.

Predicting Average Browsing Speed. Akamai's ACS was always intended to measure the browsing experience. This is important to Akamai because its service is used primarily to accelerate the browsing experience. CDNs are the Internet's "fast lane," a means of speeding up the user experience for the 10 percent of web pages they serve.⁶⁹ But this metric needs some explanation.

ACS historical curves closely match the slope of APCS curves and differ primarily in scale and variability: ACS values are about a quarter of APCS values, and ACS is more variable from quarter to quarter (Figure 49). The variability comes about because many nonnetwork factors are at work in determining the browsing experience, such as the choice of browser, computer speed, choice of applications, and number of users per IP address. Because of variations in nonnetwork factors, apparently substantial differences in network capacity do not translate to sharp differences in user experience.

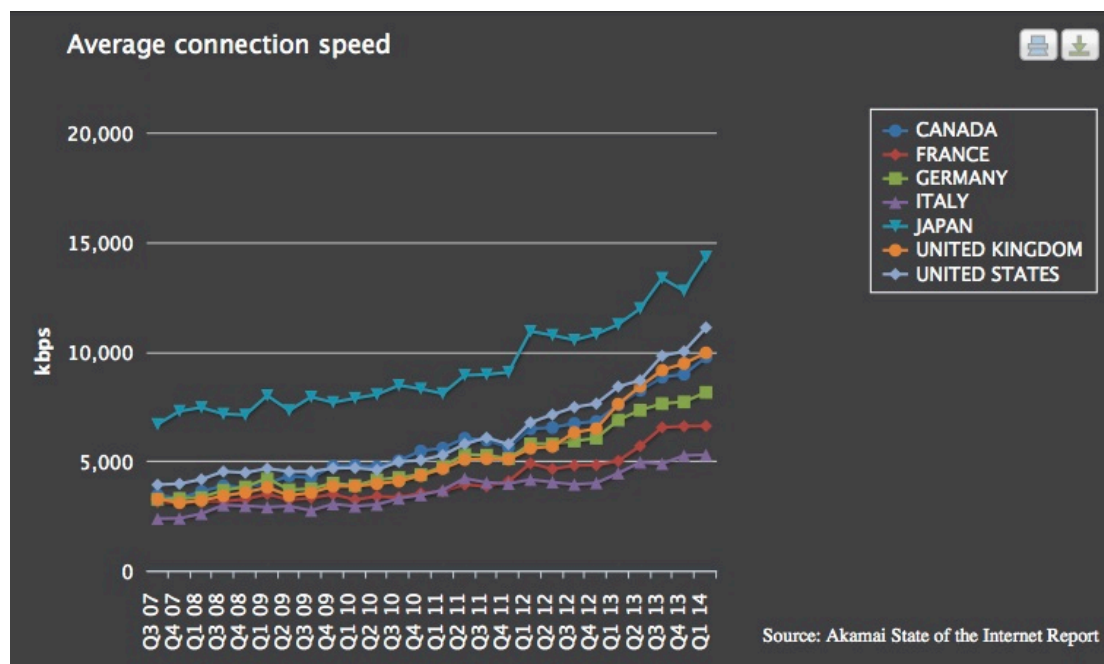


Figure 49. Browsing Experience in G7 Nations, 2007–14
Source: Akamai *State of the Internet Report*, www.akamai.com/stateoftheinternet.

HTTP Archive continually measures the average size of web pages. As of May 29, 2014, the average web page was 1,775 kilobytes.

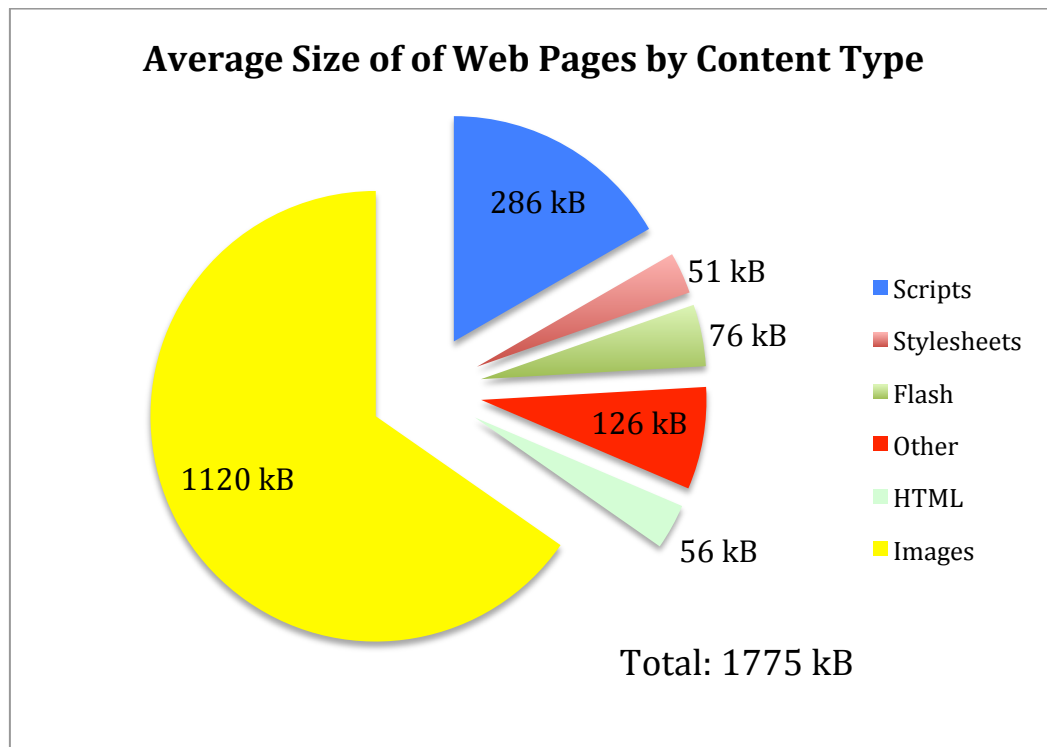


Figure 50. Average Size of Web Pages, May 15, 2014
Source: HTTP Archive, “Average Bytes per Page by Content Type.”

Browsers download from multiple TCP virtual circuits at the same time, so the fact that America’s ACS is 10 Mbps does not mean that the load time for a web page can be calculated by dividing page size by 10 Mbps; rather, page load time is more closely estimated by the average peak connection speed, reduced by a factor that accounts for IP address sharing and network congestion. Figure 51 estimates web page load time by reducing APCS by a “degradation factor” calculated from the ratio of ACS with APCS in each nation.

Server delays reduce page load times by 2 to 10 times the delay caused by the network in real measurements.

While web browsers use multiple connections at the same time, the aggregate bandwidth of these connections cannot exceed network capacity, and web pages are not always loaded over otherwise idle networks. The decay factor is similar in concept to the “promise gap” measured by the SamKnows tests, but it’s a ratio of mean to peak speed in the real world rather than a ratio of measured to advertised network capacity.

If the user experience of web browsing were completely determined by network performance, pages would load nine-hundredths of a second faster in Japan than in the US, but Japan had to build a nationwide fiber optic network (in addition to its DSL and cable networks) to achieve this benefit.⁷⁰ Users do not see web pages load this fast in the real world because server performance has a greater influence that most realize. Server delays increase page load delays by 2 to 15 times the delay caused by the network in real measurements.

The speed difference between Japan and the US on the one hand and France and Italy on the other is somewhat more evident: web pages can load in half the time in the speediest G7 nations as in the laggards. This difference is perceptible, but not truly significant; Robert Miller’s canonical human factors goal of one- to five-second response time for nontrivial interactive requests is met

by networks in all nations, even slowpokes France and Italy, but his “instantaneous” threshold of two-tenths of second is met in none.⁷¹ For all the public policy hand wringing over network performance, clients and servers primarily shape the web experience, not networks.

	ACS	APCS	Decay	Minimum Load Time	Typical Load Time
Japan	12.8	53.7	0.21	0.28	0.34
United States	10	43.7	0.22	0.36	0.43
United Kingdom	9.5	43.5	0.23	0.37	0.46
Canada	9	40.5	0.23	0.4	0.49
Germany	7.7	35.8	0.23	0.46	0.57
France	6.6	26.7	0.2	0.54	0.65
Italy	5.3	21.6	0.21	0.68	0.82

Figure 51. G7 Web Speed and Page Load Time

Sources: Calculated using web speed from Akamai, *State of the Internet Report*, and page size from HTTP Archive, “Average Bytes per Page by Content Type,” May 29, 2014.

Akamai Measurements of Actual Web Page Load Times. There is a considerable gap between the load times recorded by testing and the expected load times based on network performance. SamKnows records web page load times on the order of one second, but Akamai records times on the order of several seconds (Figure 52).⁷²

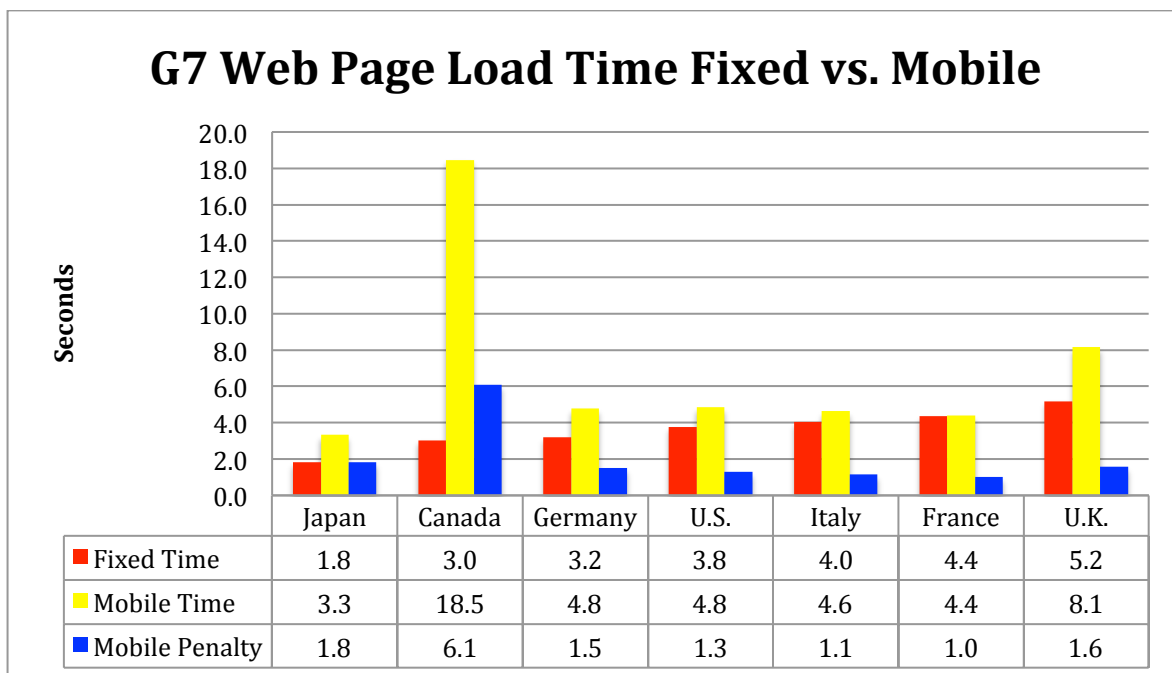


Figure 52. G7 Web Page Load Time by Network Type

Source: Akamai *State of the Internet Report*, Q1 2014. www.akamai.com/stateoftheinternet.

Note: Canada’s mobile time is exceptionally high in this period; it fell to 5.3 seconds in the Q2 2014, with a mobile penalty of only 2.3 seconds.

Analyzing web page load times on wired networks according to the contributions made by network performance and by nonnetwork factors (such as server performance, browser speed, end

user device performance, and web page organization) indicates that the role played by networks is quite small. We can calculate the delay contribution of broadband network performance to web page loading time from the average web page size and APCS figures previously cited; the remainder of web page load time can only come from nonnetwork factors. This analysis reveals radical differences in nonnetwork factors across the G7 (Figure 53).

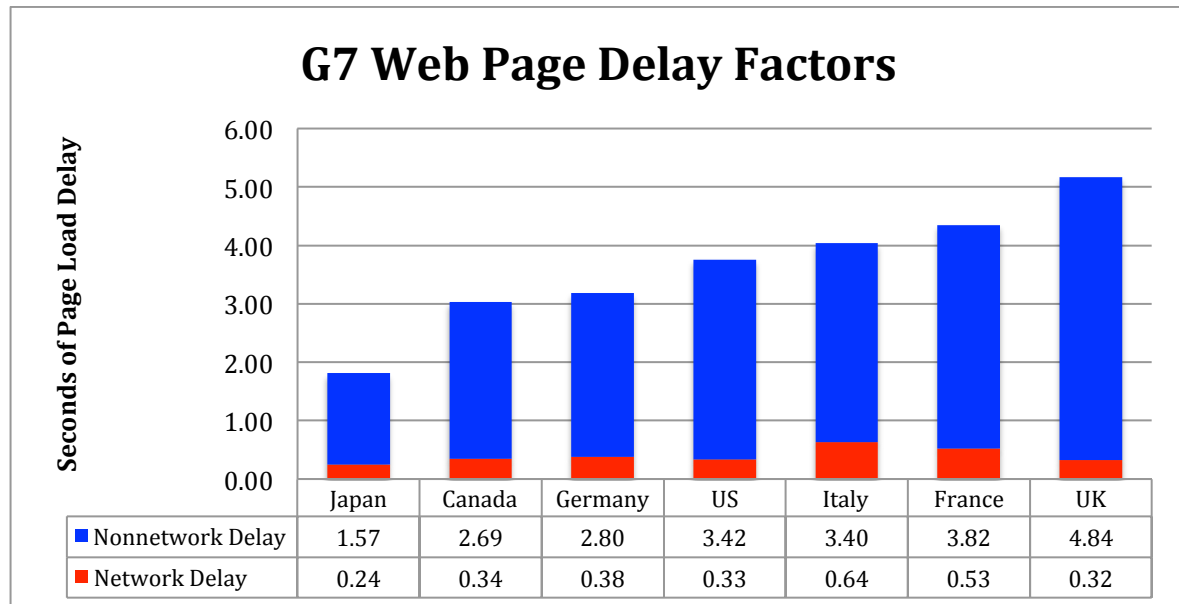


Figure 53: G7 Web Page Delay Factors.

Source: Author's analysis of web page size from HTTP Archive and average peak connection speeds and page load times from Akamai *State of the Internet Report*, www.akamai.com/stateoftheinternet

This analysis suggests that the claim that ultrafast broadband networks will lead to a “blazingly fast” Internet experience are not well founded. The FCC acknowledges this in its analysis of the load times of artificial web pages:

In specific tests designed to mimic basic web browsing — accessing a series of web pages, but not streaming video or using video chat sites or applications — the total time needed to load a page decreased with higher speeds. However, the performance increase diminishes beyond about 10 Mbps, as latency and other factors begin to dominate. For these high speed tiers, consumers are unlikely to experience much if any improvement in basic web browsing from increased speed — i.e., moving from a 10 Mbps broadband offering to a 25 Mbps offering.⁷³

Web page load time data shows that the user experience of the Internet is actually shaped more profoundly by nonnetwork factors under the control of web services firms and end users than by broadband factors under the control of network service providers. Ultrafast broadband is important enabler of post-web applications such as virtual reality and Telepresence, but it can't do much for the web.

It is interesting to note that mobile load times in France are the same for fixed and mobile networks and that mobile load times are nearly as fast in Italy as wired ones. But this should not be too surprising, given that Italy and France's wired networks are so poor and France's mobile network is so new.

Advertised Speed versus Actual Speed

SamKnows entered the network testing space on the strength of a study commissioned by Ofcom that demonstrated a large gap between advertised and actual speeds on BT's network. The United States, the EU, Singapore, and several other nations now do SamKnows testing. The focus on narrowing the gap between advertised and actual rates has led to improvement in measured network speeds.

SamKnows Data for US and Europe. SamKnows tests broadband connections in the United States and Europe to determine whether broadband suppliers deliver performance comparable to the “up to” speed they advertise. These tests are conducted by attached customized test agents—a combination of hardware and software—to selected subjects that run a suite of tests at various hours of the day and night. The SamKnows tests show that European broadband providers fail to deliver advertised speeds in almost all instances, while US providers generally exceed advertised rates for satellite and fiber systems, meet them for cable, and fall short on DSL networks.

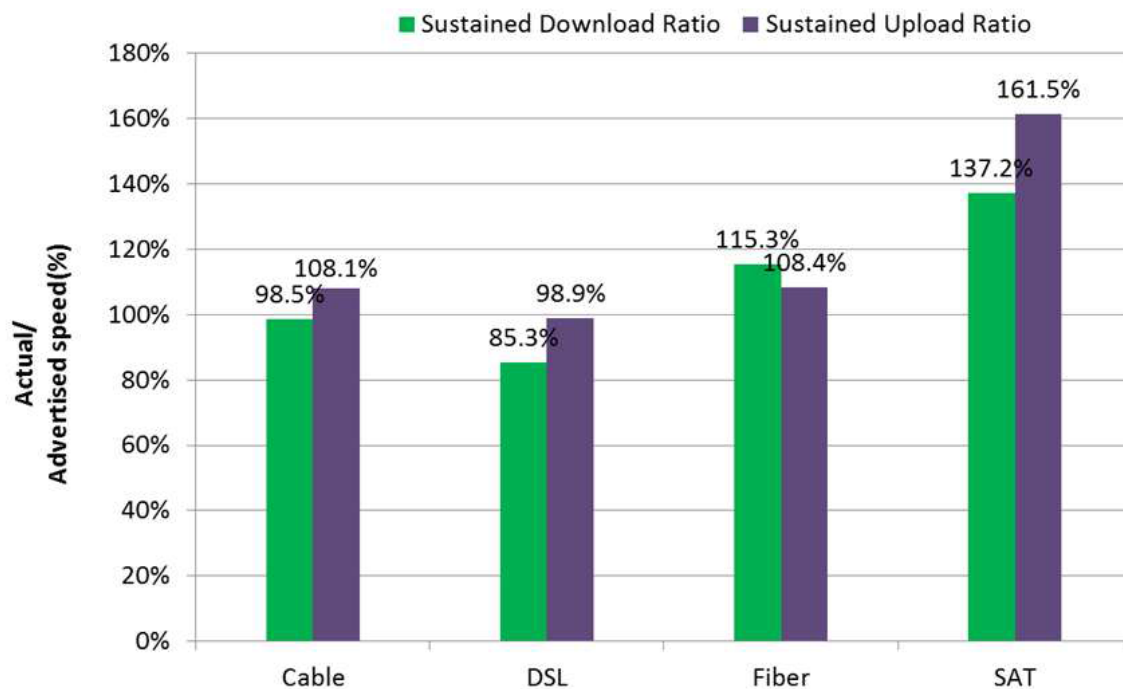


Figure 54. SamKnows Promise Index for US by Technology, September 2012

Source: FCC Office of Engineering and Technology and Consumer and Governmental Affairs Bureau, *Measuring Broadband America: February 2013 Report*.

In March 2012, Europe as a whole generally fell short on its broadband promises for DSL and fiber but generally delivered promised speeds over cable.

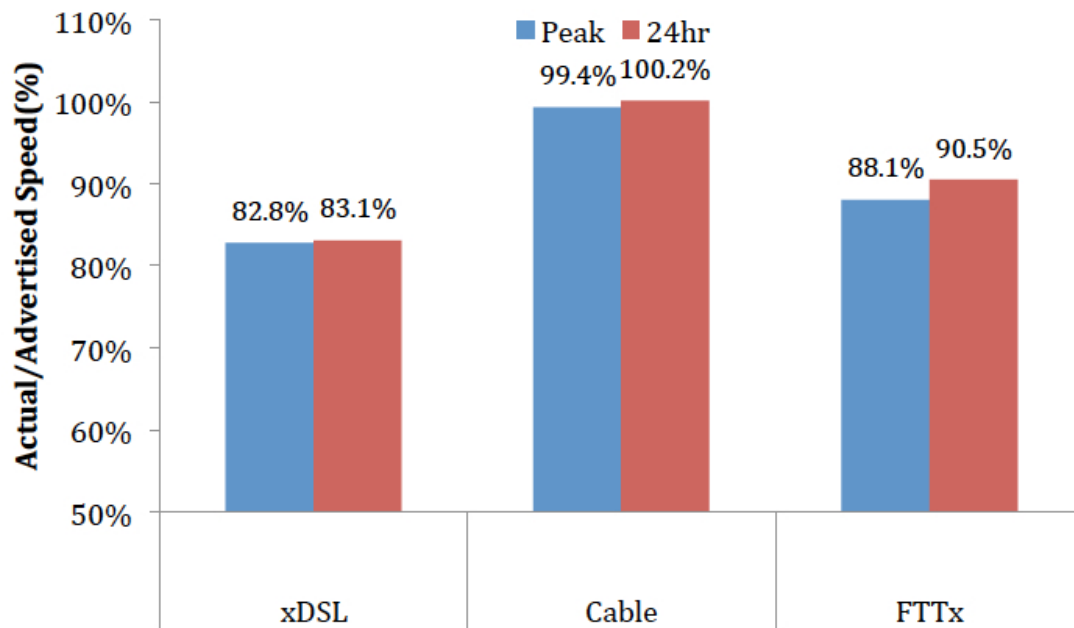


Figure 55. SamKnows Promise Index for Europe, March 2012

Source: SamKnows Limited, *Quality of Broadband Services in the EU March 2012*.

A follow-up test in March 2013 showed modest improvement, but once again only cable met its advertised claims.

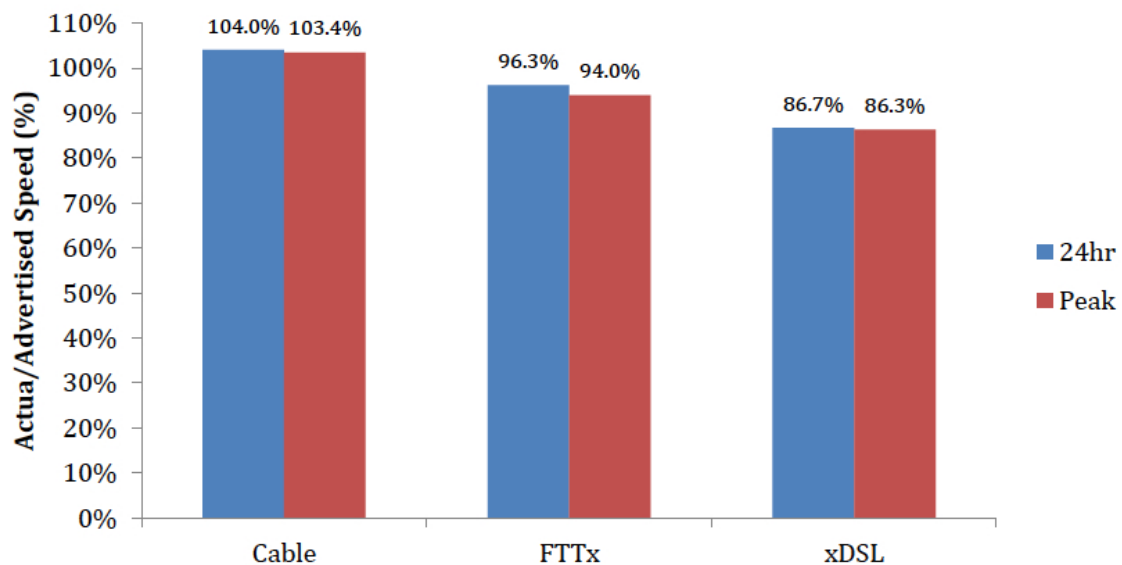


Figure 56. SamKnows Promise Index for Europe, March 2013

Source: SamKnows Limited, *Quality of Broadband Services in the EU—SamKnows Study on Internet Speeds* (second report).

SamKnows tests have been run on US networks four times: in March 2011, April 2012, September 2012, and September 2013. In all instances, the US surpassed Europe in general and

the European G7 members in particular by a wide margin in terms of delivering advertised speed (Figure 57).

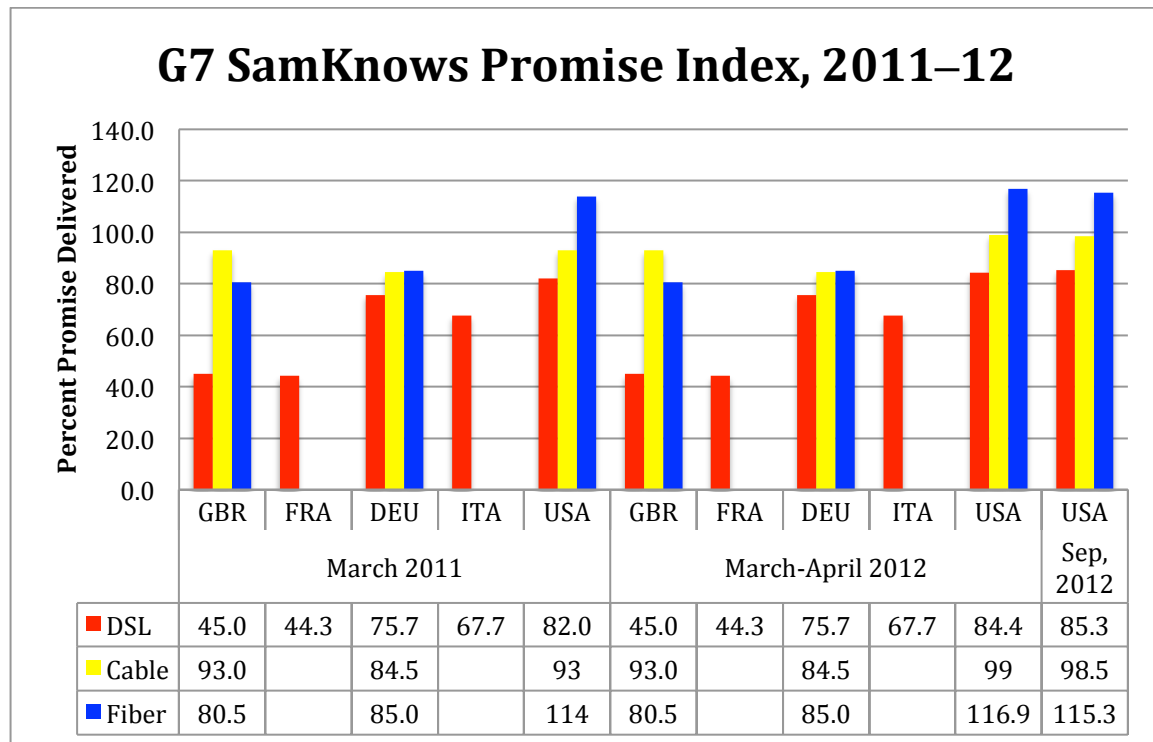


Figure 57. SamKnows Promise Index for G7 Countries

Sources: SamKnows Limited, *Quality of Broadband Services in the EU March 2012* and *Quality of Broadband Services in the EU—SamKnows Study on Internet Speeds (second report)*; FCC, *Measuring Broadband America, Measuring Broadband America: July 2012 Report*, and *Measuring Broadband America: February 2013 Report*.

The finding that the US beats Europe in terms of advertising claims is not surprising given the nature of ADSL but is peculiar for fiber. Most of Europe relies on ADSL, a technology whose performance is very sensitive to wire length; ADSL accounts for 78 percent of all active broadband connections in Europe. US broadband is predominantly cable; cable is also sensitive to distance but much less so than ADSL. While fiber is the least sensitive to distance of any broadband technology, it falls short of claims in Europe due to oversubscription of shared aggregation links. This is always a danger when firms strive for high last-mile rates without beefing up backhaul connections.

Rogers Cable of Canada voluntarily tested its network with SamKnows and reported that it exceeds advertising claims at all speed tiers (Figure 58).

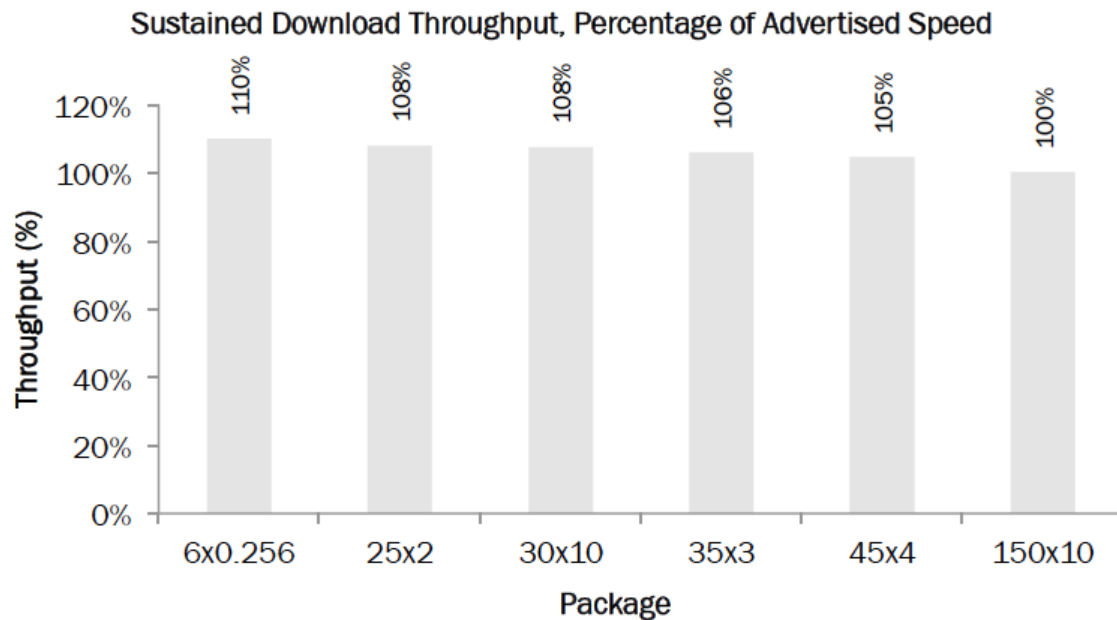


Figure 58. SamKnows Testing of Rogers Cable Canada, May 2013

Source: SamKnows Limited, *SamKnows Analysis of Rogers' Broadband Performance in May 2013, June 2013*, www.samknows.com/uploads/Rogers_Shortform_SamKnows_Broadband_Report_2013-06-28_Final.pdf.

Rogers reports that its speeds exceed the US Promise Index and responsibly does not claim an average speed on the basis of SamKnows testing: “Rogers’ peak-hour download average of 106 percent of advertised speed exceeds the US average of 97 percent.”⁷⁴ This is the correct way to use SamKnows measurements. (Note: The US now exceeds 100 percent of advertised rate across the board as well.⁷⁵)

SamKnows as a Speed Survey: Using and Misusing the Data. Europe undertook SamKnows testing to determine where its networks stood in relation to those in the US, just as the US undertook testing to compare its networks to those in the UK, the first nation to publish SamKnows data. European policymakers were not happy with the test results, so they tried to make lemons into lemonade by representing SamKnows as a test of actual network capacity rather than of advertising claims.

Network speed tests, for all their technical complexity, are surveys, fundamentally no different from any other survey in the sense that their validity depends absolutely on beginning with a representative sample of the population. SamKnows employs specialized equipment, the White Box, for testing. The White Box is a precise test instrument for networks in a particular capacity range, but its utility for conducting capacity surveys depends entirely on its distribution.

The US and Europe gave SamKnows different directions regarding the distribution of White Boxes. The US wanted to test each speed tier of each major ISP, so it required a more or less equal distribution according to that objective. Europe wanted to conduct testing by nation and technology, so it intended to adopt a distribution strategy that mirrored ISP market shares.

Europe did not distribute White Boxes according to the subscription ratios by technology reported by OECD, however. In fact, it oversampled cable and fiber and undersampled DSL. This choice artificially elevated national scores.

SamKnows and the FCC made an additional choice in the US that undermined the accuracy of SamKnows as a national speed test: it chose not to measure speeds above 75 Mbps. The FCC

admits this: “In this report for the first time we tested download speeds as high as 75 Mbps (megabits per second), and we know that even higher rates are being offered by service providers to their customers.”⁷⁶

Therefore, broadband services running at 100 Mbps and higher in the US—such as the high-end services provided by Comcast, Verizon, Google, and other gigabit networks—were entirely excluded from the US sample. According to the National Broadband Map, broadband services with download capacities of 100 Mbps and above are available to 58.2 percent of American households and 26.3 percent of rural American households.⁷⁷

It is not unreasonable to suppose that as many as 10 percent of US broadband subscriptions are for speeds of 100 Mbps or more, with as much as one-quarter of that for gigabit services.

These services are not widely adopted, nor is their adoption measured, but it is not unreasonable to suppose that as many as 10 percent of US broadband subscriptions are for speeds of 100 Mbps or more, with as much as one-quarter of that for gigabit services. Given the imputed SamKnows national average for US cable of 18.2 Mbps per second, a more complete sample would significantly raise the national average.

This is particularly troublesome given the market positioning of cable modem services in Europe. Cable modem in the UK is scarcely available at the capacity ranges SamKnows measures in the US; UK cable monopolist Virgin Media’s plans range from 50 Mbps to 152 bps. Consequently, it is not reasonable to compare US SamKnows measurements to those in Europe without adjustment, despite the European Commission’s claims to the contrary.⁷⁸

Ofcom, the UK regulator that has more experience with SamKnows than anyone else, recognizes that SamKnows is not a proper national or regional survey:

The prevalence of lower speed products in the US has resulted in lower average speeds by technology in the US than in Europe. SamKnows has conducted research on the performance of broadband in the EU and in the US and finds that average speeds for ADSL broadband, cable broadband and fibre broadband are higher across European Union countries. However, higher cable take-up in the US means that it is likely that average broadband speeds across all technologies are higher than in Europe.⁷⁹

The FCC also acknowledges that SamKnows is at best a rough survey of average national capacity (emphasis mine):

We found that, on average, customers subscribed to faster speed tiers in 2012 than in 2011. This is a result of both upgrades by ISPs to their network as well as some migration of consumers to higher speed services. To illustrate this shift, we computed the average speed offered by ISPs across all panelists in 2011 and 2012. **Due to the manner in which panelists are chosen, this provides a rough correlation** with average subscribed tiers within the United States for the participating ISPs during the testing period.⁸⁰

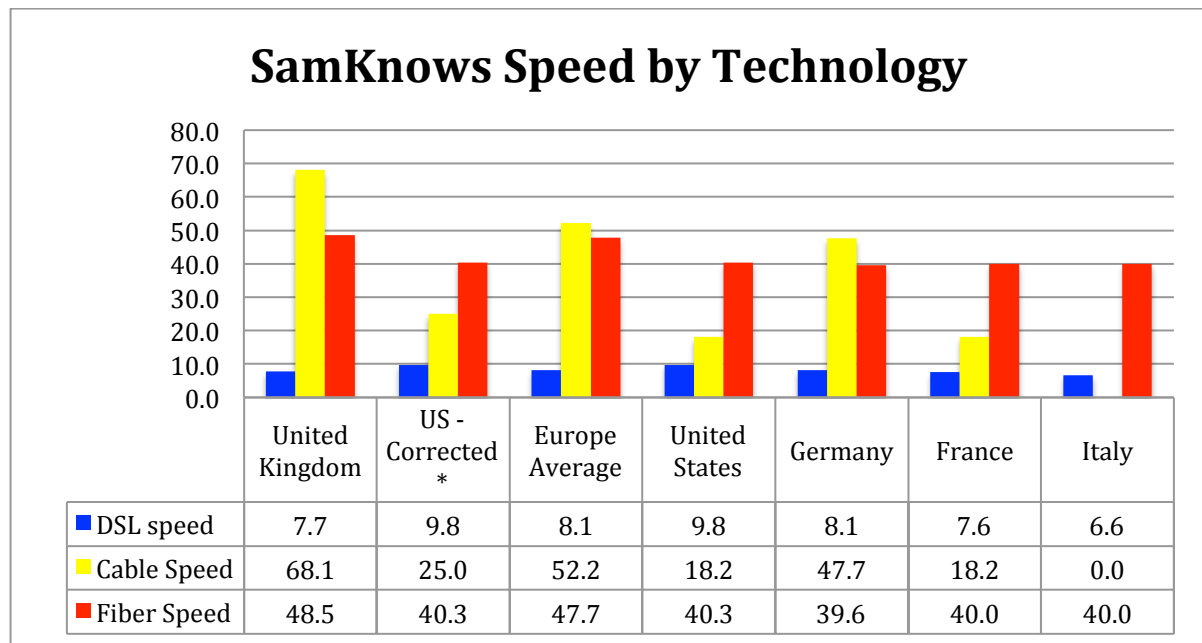


Figure 59. SamKnows Speeds in Mbps by Technology

Note: *US speed corrected for FCC deletion of high-speed connections.

Source: SamKnows Limited, *Quality of Broadband Services in the EU—SamKnows Study on Internet Speeds* (second report); and FCC, *Measuring Broadband America: July 2012 Report*.

Correcting the SamKnows data for both market share errors and undersampling of high-speed plans in the US still places the US behind the UK in average download speed, but the relationship of speeds in the two nations is reasonably close in properly sampled surveys (Figure 60). In the fourth quarter of 2013, Akamai ranked the US 10th in average capacity at 43.7 Mbps and the UK 12th at 43.5 Mbps, for example. This correction also raises the US above the European average. The US ranks above all of Europe's G7 members except UK without correction.

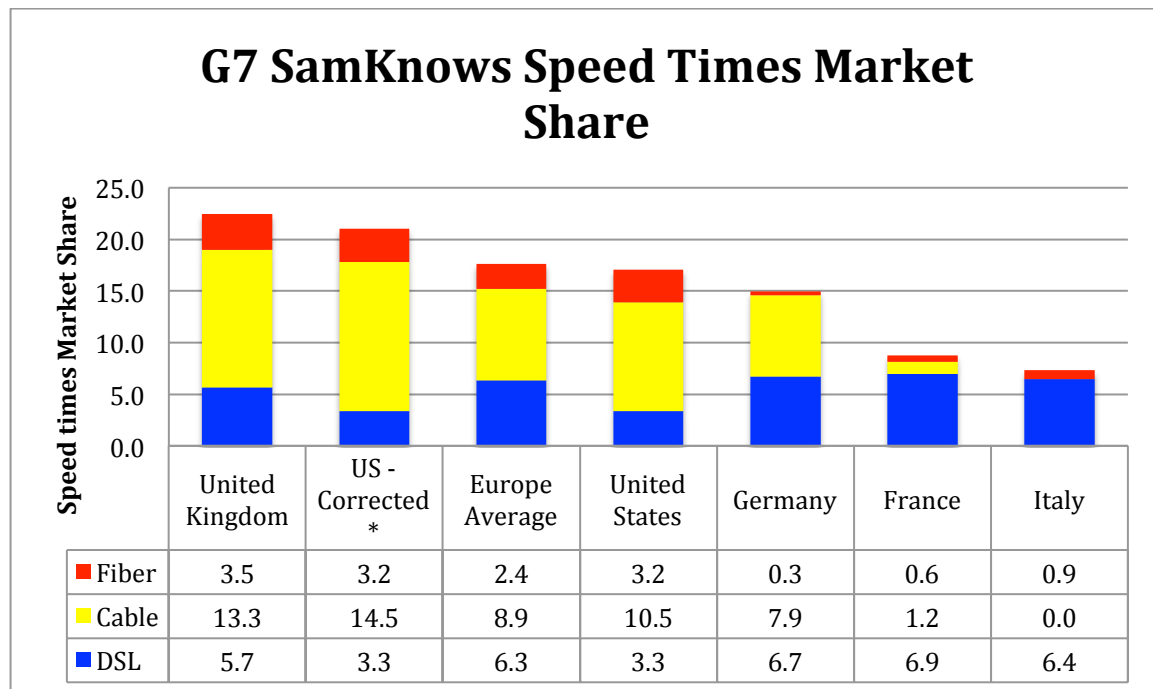


Figure 60. SamKnows G7 Download Speed Times Market Share

Note: *SamKnows does not measure speeds higher than 75 Mbps in the US, and the UK does not offer cable speeds less than 50 Mbps. Correction increases US average from 18.18 to 25 Mbps to account for this arbitrary exclusion.

Sources: Market shares from OECD, "OECD Broadband Portal"; speed data from FCC, *Measuring Broadband America: July 2012 Report*; and SamKnows Limited, *Quality of Broadband Services in the EU—SamKnows Study on Internet Speeds* (second report).

Network Utilization

Network speed is important for more than bragging rights, but it does not matter much if the networks are not used. Researchers are beginning to realize that the single most important technical dimension of networks is the amount of traffic they carry. This dimension of network quality tells us when we are close to the right balance of price, speed, coverage, and digital readiness; we cannot use networks heavily if they are not effectively usable. Increases in traffic load are also signals to network providers to upgrade speeds; the higher the signaling rate of a network, the more traffic it can carry.

South Koreans are the heaviest users of Internet data, with the US in second place and climbing.

Network utilization can be measured by ISPs and by crowdsourcing; in both cases, data have to be saved across system reboots and crashes and cleared for each measurement period. Based on observations commissioned at exchange points, Cisco projects future utilization based on observed trends. These projections indicate that South Koreans are the heaviest users of Internet data, with the US in second place and climbing. Canada and the UK, two other English-speaking nations with extensive

bimodal networks, follow the US among G7 nations. The nations in continental Europe with slower wired networks bring up the rear, but France appears to be keener on the Internet than Germany and Italy.

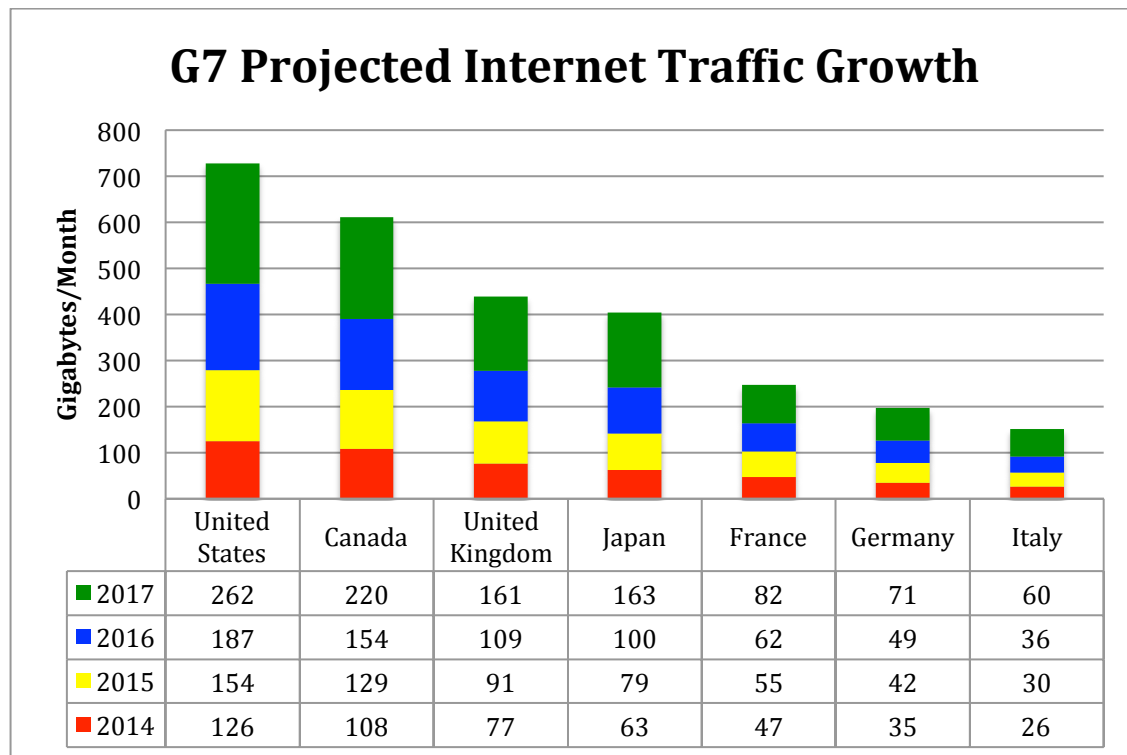


Figure 61. Projected Internet Traffic in Gigabytes per Household per Month
 Sources: Cisco; World Bank, "Population (Total)"; and NationMaster, "Countries Compared by People > Average Size of Households, International Statistics at NationMaster.com."

In terms of mobile traffic, the picture is quite different.

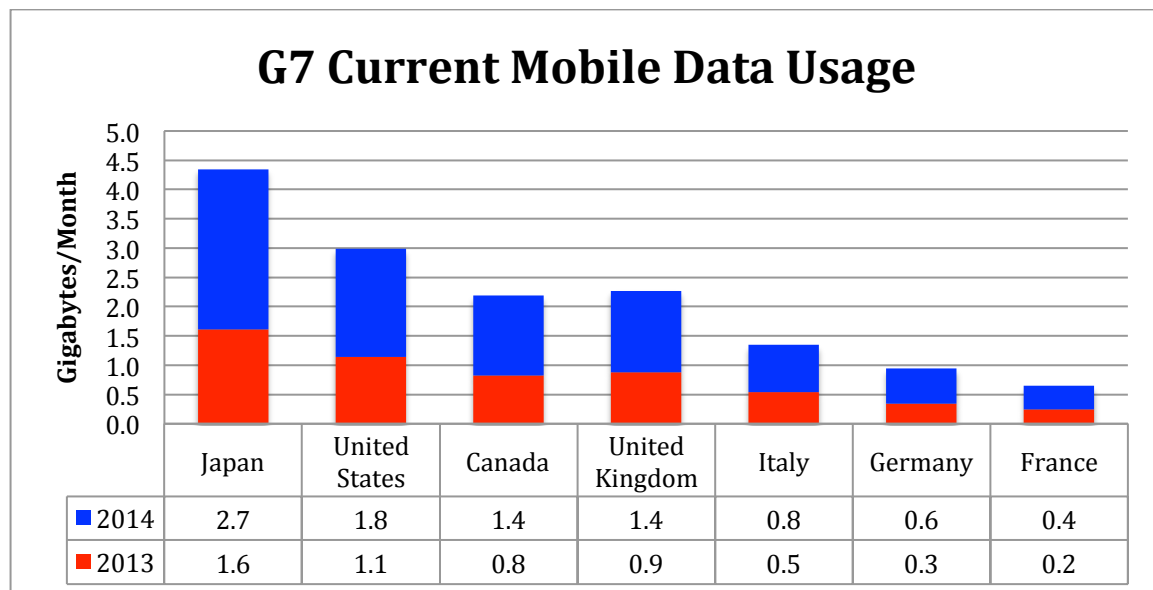


Figure 62. G7 Estimated Current Mobile Data Usage per Household
 Sources: Cisco; World Bank, "Population (Total)"; and NationMaster, "Countries Compared by People > Average Size of Households, International Statistics at NationMaster.com."

Cisco estimates that Japan has the highest mobile data usage; France, Germany, and Italy have the lowest, and the US, Canada, and the UK are in the middle. The gap between highest and lowest is 8:1, a larger spread than the data show for wired connections, where the gap between the US and Italy is 5:1.

It is hard to square this estimate with the data on smartphone adoption, but it reflects trends in application usage as well as devices; Japan has relatively low smartphone adoption but high usage of mobile video by commuters. For both wired and mobile, Cisco foresees the gap between the nations reducing, but not substantially.

Broadband Prices

Broadband prices are often surveyed through questionnaires and occasionally by reviewing advertising, but these methods are unlikely to yield meaningful results; for one example, see OECD's pricing criteria.⁸¹ Advertising surveys can reveal significant results if they are extremely thorough; the survey of European and US prices conducted by Van Dijk Management Consultants for the EU in 2012 is a good example.⁸²

Good and Bad Criteria

Pricing surveys often fall prey to a common faulty metric, comparison in terms of dollars per Mbps, which assumes that either the cost or the value of a 1,000 Mbps connection is 100 times that of a 10 Mbps one; OECD research is very fond of this way of measuring. It is reasonable to compare prices for a given level of speed in different locales, as the Van Dijk study does, but less reasonable to compare the value of plans offering different speeds to one another. It is not clear what the following OECD graph is meant to measure, for example:

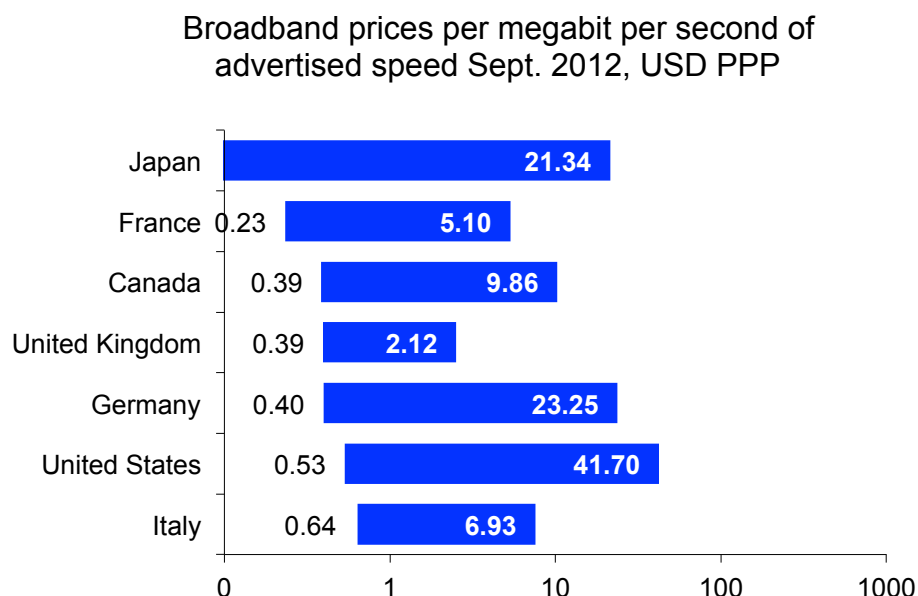


Figure 63. OECD Price Comparisons for G7 Nations

Source: OECD, "OECD Broadband Portal."

Cost and value are not linear functions of speed, and since these prices were collected some large ISPs in the US have quadrupled speeds for middle-tier service plans.⁸³ This places such plans beyond the speed ranges achievable in the EU without network upgrades. Manufacturing volume drives technology costs, and today gigabit (1,000 Mbps) fiber transceivers are cheaper than 100 Mbps ones in spite of having 10 times the capacity.

Errors of Selection and Omission

The advertising survey method is used by the New America Foundation's *Cost of Connectivity* report as well, a report that compares the prices of Internet services in both urban and rural US

cities and towns to European capitals.⁸⁴

City	ISP	Subsidy	NAF Price	License Fee	Price w/ Lic Fee	Adv D/L Speed	200 Chan US Content
Paris	Free	Yes	\$35	\$15	\$50	28	No
Paris	SFR	Yes	\$35	\$15	\$50	25	No
Paris	Bouygues Telecom	Yes	\$37	\$15	\$52	20	No
Paris	Darty	Yes	\$37	\$15	\$52	20	No
Bristol, VA	BVU	Yes	\$55	\$0	\$55	6	
Berlin	Tele-Columbus	Yes	\$34	\$25	\$58	16	No
London	Sky	Yes	\$38	\$20	\$58	16	No
Berlin	Kabel Deutschland	Yes	\$36	\$25	\$61	32	No
Lafayette, LA	LUS	Yes	\$65	\$0	\$65	15	Unknown
Washington, DC	RCN	No	\$68	\$0	\$68	25	Yes
Los Angeles	Verizon	No	\$70	\$0	\$70	15	Yes
New York	Verizon	No	\$70	\$0	\$70	15	Yes
New York	Time Warner Cable	No	\$75	\$0	\$75	15	Yes
Lafayette, LA	AT&T	Yes	\$79	\$0	\$79	6	Yes
Los Angeles	Time Warner Cable	No	\$80	\$0	\$80	15	Yes
Washington, DC	DSL	No	\$80	\$0	\$80	15	Yes
Chattanooga, TN	EPB	Yes	\$82	\$0	\$82	100	Unknown
New York	RCN	No	\$90	\$0	\$90	25	Yes
San Francisco	Comcast	No	\$99	\$0	\$99	25	Yes
Bristol, VA	Charter	No	\$100	\$0	\$100	30	Yes
Kansas City, KS	Time Warner Cable	No	\$100	\$0	\$100	15	Yes
Los Angeles	AT&T U-Verse	No	\$109	\$0	\$109	18	Yes
Kansas City	Time Warner Cable	No	\$112	\$0	\$112	10	Yes
Washington, DC	Comcast	No	\$113	\$0	\$113	20	Yes
Lafayette, LA	Cox	No	\$121	\$0	\$121	5	Yes
Chattanooga, TN	AT&T	No	\$133	\$0	\$133	6	Yes
San Francisco	Astound	No	\$134	\$0	\$134	15	Unknown
Chattanooga, TN	Comcast	No	\$151	\$0	\$151	20	Yes

Figure 64. Triple-Play Prices in Some G7 Cities and Towns, Including Content Fees

Sources: New America Foundation, *The Cost of Connectivity 2013*; and Roslyn Layton and Michael Horney, *Innovation, Investment, and Competition in Broadband and the Impact on America's Digital Economy*.

New America fails to select comparable bundles of broadband and TV, comparing 50-channel international bundles to 200-channel US triple-play plans; it omits content fees (TV license fees) international customers pay; and it omits subsidies received by US municipal networks and over-the-top ISPs in Europe (below-cost access to incumbent lines is effectively a subsidy). When content fees are included, it is clear that the actual cost of connectivity is not as high in the US as we have been led to believe (Figure 64).

Leaving aside New America's omissions, the advertising survey method cannot capture representative prices real consumers pay because current advertising does not include prices paid under old contracts.⁸⁵ There is also no guarantee that prices obtained from surveyed ads are apportioned correctly across the user population.

Price Surveys

The Van Dijk report previously mentioned confirms findings by the Berkman Center and ITU that US broadband prices tend to be lower than those in Europe for low speeds ("entry level") and higher for higher speeds (Figure 65).⁸⁶

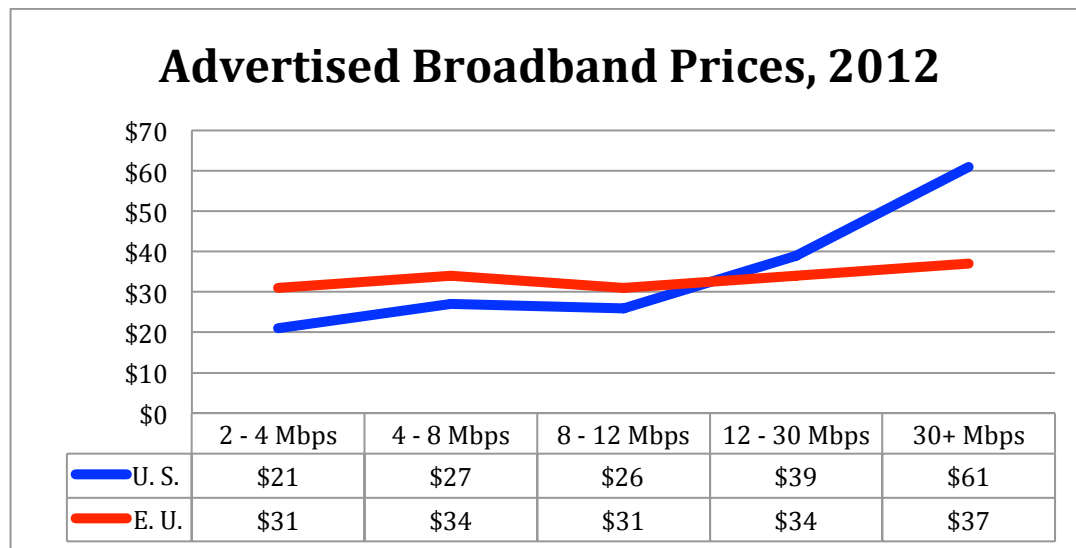


Figure 65. Broadband Prices by Speed, US and EU, 2012

Source: Van Dijk Management Consultants, *Broadband Internet Access Cost*.

Van Dijk also collects limited data from Canada and Japan, so it is possible to compare least price offers by speed tier across the G7 with this data set. When we do this, we find that the US offers the least expensive prices in the G7 for the 8–12 Mbps speed tier and the second lowest in the 4–8 Mbps tier (Figure 66). US prices are roughly average at the 12–30 Mbps tier and above average at the 30+ Mbps tier. The Van Dijk 2–4 Mbps data is incomplete with respect to the G7. It should be noted that US prices for high-speed tiers have probably declined substantially since 2012 because Comcast has doubled the speeds of its middle tiers without increasing prices twice since early 2013.

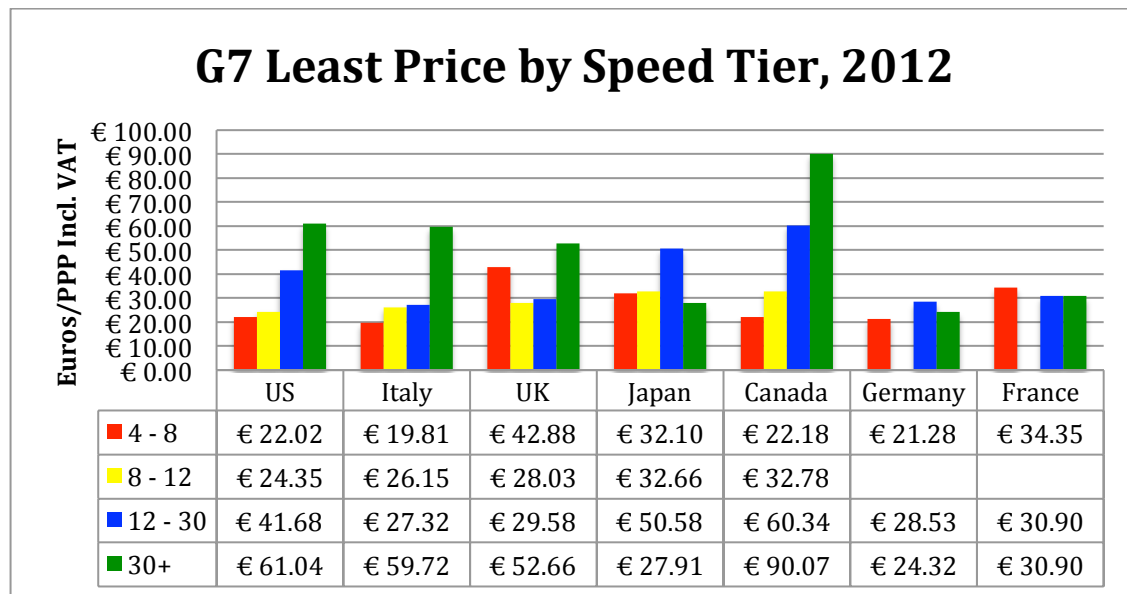


Figure 66. G7 Least Price by Speed Tier, 2012

Note: No data for Germany and France in the 8–12 Mbps tier.

Source: Van Dijk Management Consultants, *Broadband Internet Access Cost*.

Consumer surveys are a reasonable approach as long as they do not ask detailed questions about upload and download speeds. (Consumers consistently fail to identify speeds correctly, probably because they increase so rapidly.) Point Topic also engages in general consumer price surveys.

For all forms of broadband, Point Topic ranks all of the G7 below the global average of monthly subscription fees paid for standalone broadband services (Figure 67). Point Topic rates the US and Canada at the high end of the G7, France and Japan at the low end, and the rest of Europe in the middle. Point Topic does detailed pricing surveys for the EU now, but its findings do not mesh very well with the other estimates of prices paid for standalone broadband.

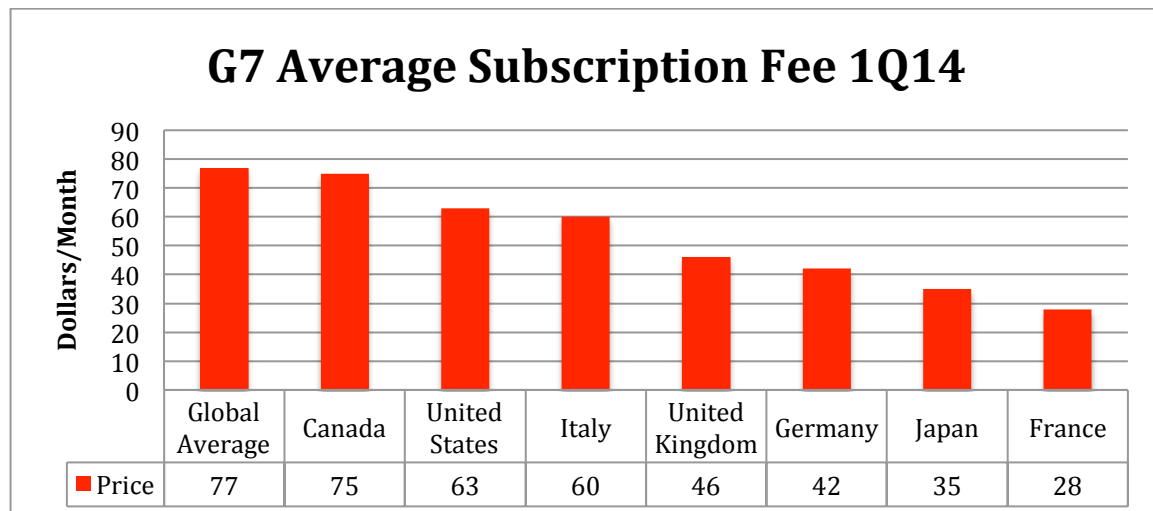


Figure 67. Average Monthly Broadband Prices for Standalone Residential Services, Q1 2014

Source: Point Topic, "Broadband Tariff Country Scorecard—Q1 2014."

Because of the variations in survey data, it is more prudent to establish prices paid on the basis of average revenue per user (ARPU) figures calculated by consultancies from financial data where they are available (though of course, ARPU cannot be thought of as a price per se, as it does not account for variations in quality and usage). At the moment, we can get ARPU only from financial statements for mobile broadband, so it is necessary to rely on survey data for wired broadband. Mobile ARPU data are taken from Infonetics Research's *Telecommunications Market Research: Telecom Market Analysis: Third Edition* and the Bank of America/Merrill Lynch *Global Wireless Matrix*.⁸⁷ Wired prices come from Point Topic surveys.⁸⁸

Perceived Value

Boston Consulting Group estimates the cost and perceived value of Internet use in five of the G7 nations. Curiously, its analysis generally places the highest value on the use of the Internet in nations with the least intensity of Internet use, the lowest contribution of the Internet economy to GDP, and the highest subscription prices (Figure 68). In the group's analysis, email, search, and banking were the most valuable uses of the Internet.

The tendency of those with low-quality broadband connections to attribute massive value to Internet use raises interesting questions about notions such as "consumer surplus" that depend on imputed willingness to pay.

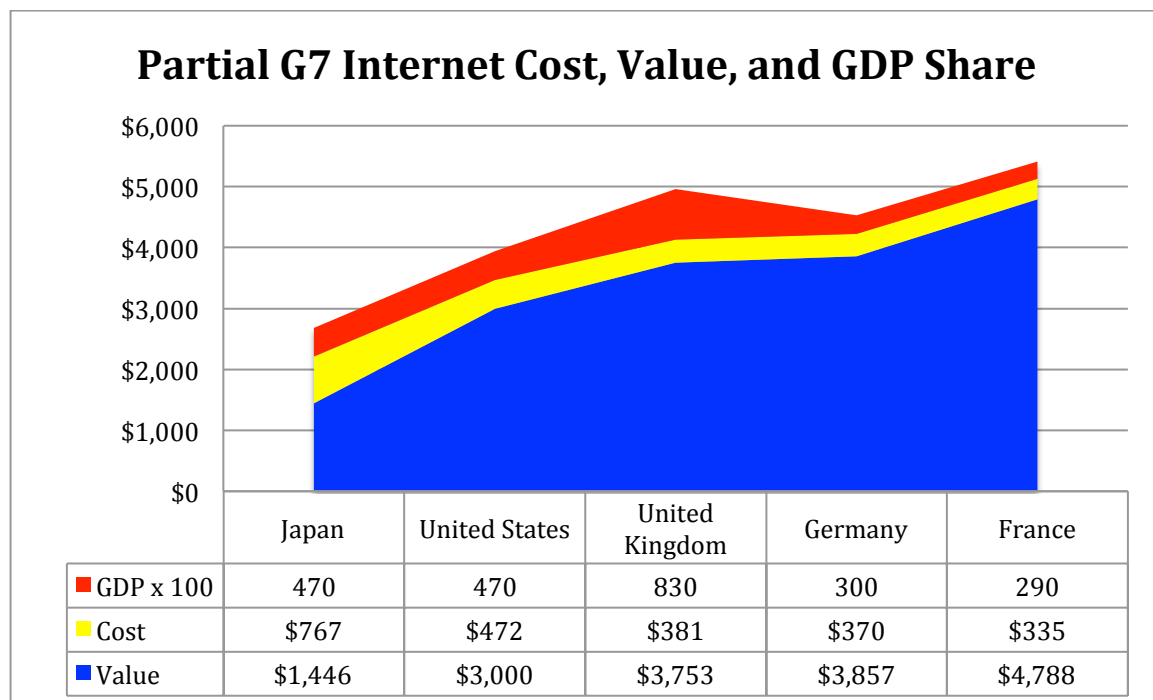


Figure 68. Partial G7 Internet Cost, Perceived Value, and Contribution to GDP

Source: David Dean et al., *The Connected World: The Internet Economy in the G20*, Boston Consulting Group, March 2012.

Consumer Value

In attempting to calculate broadband value, many analysts make naïve comparisons on the basis of consumer prices per Mbps of capacity.⁸⁹ This method is inappropriate for two reasons: first, it assumes the costs of building and operating networks are the same in all locales and at all levels of load, when they clearly are not, and second, it assumes that consumer value increases linearly with last-mile capacity. In the real world, network costs are a function of distance and load.

Internet transit services are priced on the basis of volume and distance because these factors reflect real costs of service.

In a more realistic assessment, cost factors such as distance, density, and traffic volume must be included, and capacity evaluations must recognize diminishing returns for speeds above the utility threshold.⁹⁰ Internet transit services are priced on the basis of volume and distance because these factors reflect real costs of service; beyond the point of being able to use all the applications the user wishes to use, capacity has little value.⁹¹ Unfortunately, the data on network costs are not always sufficient to support such analysis; we can do a lot better with mobile networks than with wired ones, but not as well as we would like.

A comprehensive review of the prices paid in G7 nations in relation to provider costs and consumer service quality is beyond the scope of this analysis. It is, however, an intriguing subject for future research that has not yet been dealt with in an entirely satisfactory manner.

Policy Analysis

Now that we have surveyed the data on deployment, adoption, performance, price, and value, we are in a position to assess the policies that have helped produce these results. The policy choices of interest follow from the following goals:

1. Universally available service
2. Universal adoption
3. Continual technology displacement
4. Low consumer price
5. Increasing consumer value

These five pillars of broadband policy are often in tension with one another. Technology displacement, for example, requires capital investment. Investment comes at the expense of consumer prices, even though it may increase consumer value in the long term—for example, enabling consumers to reap positive externalities that come from making tomorrow’s networks better than today’s.

Universal service is a prerequisite to universal adoption but at the same time, a barrier; to the extent that consumers in first-served locales are attracted by low prices, carrier profits may be trimmed to the point that extending service into higher-cost locales is unattractive. Subsidizing rural service can resolve this dilemma, but doing so raises the social cost of broadband, albeit in a way that may go unnoticed by voters and even by regulators.

Initial US Policy

The history of US broadband policy tends to be poorly understood because of two intertwining issues: intermediary liability and access to infrastructure. Common carrier law protects service providers from liability for the actions of their users: if you and I conspire to commit a crime in a series of telephone calls, the telephone company cannot be held responsible for our actions. Third-party liability for these often-criminal actions taking place over the broadband network was not firmly decided until the court ruled, in the 1997 *Zeran* case, that Section 230 of the Digital Millennium Copyright Act protected online services from the consequences of their users’ actions.⁹² Prior to this seminal decision, some broadband carriers were drawn to common carrier treatment for liability reasons.⁹³

When the FCC initially classified DSL as a Title II common carrier service in its 1998 Advanced Services Order, carriers Bell Atlantic and SBC Telecom asked the commission to use the specific “forbearance authority” granted by Section 706(a) of the 1996 Telecommunications Act to refrain from imposing Title II open-access and price-control regulations on DSL.⁹⁴ The FCC argued that it lacked this authority, and the court affirmed the FCC’s reading of the law. The FCC and some advocates now claim, interestingly, that Section 706(a) does grant broad authority to forbear from any and all provisions of Title II as it wishes.

Broadband provided over cable has never been classified a common carrier service by the FCC, although it did hold that status within the Ninth Circuit’s jurisdiction from 1999 until the FCC formally classified it under Title I in 2002.⁹⁵

The Great Pivot

After the Supreme Court upheld the FCC’s Declaratory Ruling classifying Internet access over cable modem as an “Information Service” in the *National Cable and Telecommunications Association v. Brand X Internet Services* case in 2005, the FCC reclassified DSL as an

Information Service as well.⁹⁶ This put an end to mandatory LLU (“open access”) in the United States.

These actions were widely anticipated; hence, the notion of “net neutrality” as a potentially superior regulatory policy was already under development. Tim Wu’s first memo on net neutrality was written in 2002, and his first journal article was written shortly thereafter.⁹⁷ Wu’s article, “Network Neutrality, Broadband Discrimination,” argues that net neutrality is a stronger tool than unbundling for preventing anticompetitive vertical integration while permitting beneficial integration:

True application neutrality may, in fact, sometimes require a close vertical relationship between a broadband operator and Internet service provider. The reason is that the operator is ultimately the gatekeeper of quality of service for a given user, because only the broadband operator is in a position to offer service guarantees that extend to the end-user’s computer (or network). Delivering the full possible range of applications either requires an impracticable upgrade of the entire network, or some tolerance of close vertical relationships.

This point indicts a strict open-access requirement. To the extent open access regulation prevents broadband operators from architectural cooperation with ISPs for the purpose of providing QoS dependent applications, it could hurt the cause of network neutrality. By threatening the vertical relationship required for certain application types, it could maintain IP’s discrimination in favor of data applications. More broadly, this argument shows that the concept of network neutrality cannot be taken as counsel against all vertical integration.⁹⁸

The FCC’s classification of cable modem as an Information Service and its corresponding reclassification of DSL was intended to stimulate the broader deployment of advanced broadband

US broadband policy has largely remained as it was in 2005.

networks across the US. The US had this policy option—relying on competition rather than regulation to achieve national goals—because we had competing broadband facilities and a legal framework that directed the FCC to stimulate the deployment of “advanced networks” in Section 706(a) of the 1996 Telecommunications Act.

US broadband policy has largely remained as it was in 2005: the market is generally deregulated apart from on-again, off-again net neutrality strictures, and unhappy advocates for greater regulation continue to make a case for greater government intervention, often on a flawed factual foundation.⁹⁹

Other G7 Case Histories

Facilities-based competition was not an appealing option in most of the G7 until nations confronted the issue of technology upgrades that required new or reconfigured wiring. Europe and Japan still employ official policies that mandate a right of wholesale access to the DSL incumbent’s lines in the interest of promoting low prices and competition between ISPs, but the details of wholesale access terms can have the effect of nullifying the policy.

If the access price is too high to be attractive to would-be retail ISPs, the open-access regime effectively becomes a facilities-based model. If they are too low, the system stagnates and consumers have little incentive to choose higher-performing but more costly upgrades. By its nature, low-priced mandatory wholesale access is a boon to adoption and a barrier to technical progress. The following section is an attempt to tease out the implementation of price controls

and subsidies to determine where the rest of the G7 stands with respect to this delicate policy balance.

Canada. Canada's broadband policy is a close cousin of America's: in urban markets, broadband is largely deregulated, and in rural areas, it is heavily subsidized.¹⁰⁰ For all practical purposes, Canada and the US follow the same regulatory model; it can be termed the "Pioneer Model" as it rewards first movers and risk takers.

As the population data show, Canada's rural population is sparse, with an average rural density of 14 persons per square kilometer of arable land. Canada's north features vast, sparsely populated areas. For reasons that become obvious upon inspection, satellite and terrestrial wireless networks serve these regions, not wireline.

Canada's broadband policy is a close cousin of America's: in urban markets, broadband is largely deregulated, and in rural areas, it is heavily subsidized.

Twenty five communities in Nunavut, Canada's largest and northernmost territory, house 30,000 people across two million square kilometers. Canada's rural population spread is similar to Alaska's, a state in which half the people live in one city. There is a degree of competition even in these remote areas, however. While one firm, SSI Micro, maintains backhaul facilities, local Internet services are provided by community service providers.

Canada's national broadband plan, *Connecting Rural Canadians*, was enacted in 2010. It emphasizes subsidy programs, matching grants, and federal/provincial partnerships. Canada continues to raise speed targets; in 2011, CRTC established a goal of 5 Mbps for all Canadians by 2015.¹⁰¹ Without increased spending in remote areas, this target will not be achieved.

In 2014, Canada's Ministry of Industry published a plan to stimulate the larger digital economy, *Digital Canada 150*.¹⁰² This plan adds \$305 million to the rural subsidy budget toward the 5 Mbps goal but scales the goal back to 98 percent of Canadians.

Digital Canada 150 is a broad program that deals with subjects ranging from channel unbundling to cyberbullying, but the emphasis on the infrastructure portion (apart from rural subsidies) is primarily on mobile, particularly on the desire to lower mobile service bills.

Canada clearly considers urban broadband infrastructure a solved problem and seeks to stimulate more effective utilization.

Japan. Professor Toshiya Jitsuzumi of Kyushu University in Fukuoka, Japan contributes the following account of Japan's broadband policy history:

Broadband service in Japan was first provided by a cable firm (Musashino-Mitaka Cable Television) in Tokyo in October 1996, and first ADSL became available in Nagano prefecture in August 1999. However, at the turn of the century, Japan's Internet penetration was the lowest among developed nations as most accessed the Internet via POTS or ISDN; broadband users were less than 5%. In order to improve this situation -- and make Japan the most advanced IT nation in the world -- the Japanese government passed the IT Basic Law in November 2000, created the IT Strategy Headquarters in January 2001, and mapped out a strategy called the "e-Japan Strategy."

The e-Japan Strategy found that significant reasons behind the unacceptable status quo included high access fees and old-fashioned regulations, the former of which were considered to be the result of the overwhelming dominance of the local communications market by NTT-East/West (NTT-E/W). It targeted the development of the world's top network, with broadband available to more than 30 million households and ultra-broadband (over 30 Mbps) available to more than 10 million households within 5 years.

Then, it called for creating fair competition in the telecom sector and facilitating fiber deployment. To this end, the Ministry of Public Management, Home Affairs, Post, and Telecommunications (MPHPT), which was then renamed to the Ministry of Internal Affairs and Communications (MIC), utilized the already-introduced asymmetric regulation, interconnection rules, and other related policies in the Telecommunications Business Act. These initiatives finally enabled Japan to achieve its target in only three, not five, years. The asymmetric regulation stipulates the owner of dominant local network (in this case, NTT-E/W) to make its network widely available for any competitors in favorable conditions and does not allow it to prioritize any partner companies; it is widely believed that this asymmetric regulation, accompanied with NTT's own initiative for open networks made public in February 1995, paved the way for the success of competitive broadband firms, especially ADSL providers, and greatly helped Japan to achieve its goal.

Since then, the primary focus of Japanese ICT strategies (e-Japan II in 2003, IT New Reform Strategy in 2006, i-Japan Strategy 2015 in 2009, New Strategy in Information and Communications Technology in 2010, and Declaration to be the World's Most Advanced IT Nation in 2013) shifted from expanding broadband coverage to promoting its usage. Expanding broadband coverage to the nationwide market was mostly done by private initiatives, firstly of ADSL operators and then of FTTH providers. The MIC helped their businesses through interconnection rules, reducing access fees to existing network infrastructure, settling disputes among operators, and issuing direct orders if needed. It is important to note that, since the terms of local loop unbundling of fibers could not fully satisfy the need of competing providers, competition in the FTTH deployment is far less than ADSL's. The main concern for unbundled fiber is that competitors cannot lease a single strand; instead, they have to use a bundle of eight strands even if they need only one strand. This makes it difficult for competitors to make profits in the fiber retail market. On the other hand, competitors can lease a single metal line from NTT-E/W; thus, they can offer competitive ADSL services in the retail market.

According to the MIC, as of September 2007, 79.3% of local fibers were installed by NTT-E/W and 70.7% of the retail market has been controlled by them.¹⁰³ On the other hand, NTT-E/W installed 99.96% of copper lines, which can be converted into ADSL, but controlled only 37.4% of the retail market. NTT-E/W's joint market share in the growing retail FTTH market reached 72.5% as of March 2013.¹⁰⁴ However, as it was considered insufficient to rely solely on private incentives to realize ubiquitous broadband availability, the MIC formulated the Strategy on Bridging the Digital Divide in 2008, financially supporting municipal FTTH projects. In 2010 the MIC set a new target -- realizing ultra-broadband availability, or coverage, at all households by around 2015. Thanks to these efforts and competition among private providers, as of the end of March 2013, ultra-broadband was available to 99.4% of all Japanese households (53.81 million households) and broadband to 100%.

On May 2014, NTT holding company declared that it will start providing wholesale fiber access services by NTT-E/W sometime after the 2014Q3; as of the end of September 2014, the MIC seems to approve it. Although concrete terms and conditions are yet to be announced, it is expected that the wholesale fiber can be leased on a single strand basis. If that is the case, it may have a significant impact on the business prospects of other facility-based competitors.¹⁰⁵

Year	Japanese Government ICT Initiatives
2000	IT Basic Law
2001	IT Strategy Headquarters
2001	e-Japan Strategy
2003	e-Japan Strategy II
2006	New IT Reform Strategy
2009	i-Japan Strategy 2015
2010	New Strategy in Information and Communications Technology
2013	Declaration to be the World's Most Advanced IT Nation

Figure 69. Japanese Government ICT Initiatives

Source: Compiled by Toshiya Jitsuzumi from various sources.

Broadband Availability among Japanese Households		
	Ultra-broadband	Broadband
June 2006	81.0 percent	95.0 percent
March 2007	83.5 percent	n.a. (95.2 percent)
March 2008	86.5 percent	n.a. (98.3 percent)
March 2009	90.1 percent	99.7 percent (98.8 percent)
March 2010	91.6 percent	99.9 percent (99.1 percent)
March 2011	92.7 percent	100 percent (99.2 percent)
March 2012	97.3 percent (96.5 percent)	100 percent (99.7 percent)
March 2013	99.4 percent (97.5 percent)	100 percent (99.8 percent)

Figure 70. Broadband Availability among Japanese Households

Note: Numbers in parentheses are household coverage by fixed broadband.

Source: MIC, "Competition Review in the Telecommunications Business Field 2012" (in Japanese).

In summary, Japan used the open-access regime for leverage to achieve the goal of universal ultra-broadband ahead of market demand. It achieved this result by setting wholesale access rates too low for NTT-E/W to achieve profitability from the copper network alone. Simultaneously, it allowed NTT-E/W greater flexibility with the terms and conditions of FTTH line sharing, making it clear that NTT-E/W needed to invest in FTTH if the newly privatized firm was to become profitable. The effects of the two policies are clear in the market shares for DSL and FTTH: NTT-E/W has 37.4 percent of the market for retail DSL and 70.7 percent of the retail market for FTTH. Competitors can buy dark fiber from NTT-E/W, but only in groups of eight strands at a time. This form of conditioning access to volume is known as the Contingent Model in Europe, where it is the norm for advanced network access in Germany and, to a certain extent, in the UK.¹⁰⁶

Below-wholesale prices for DSL depress the market rate for FTTH, however, and Japan's wired broadband industry generates negative cash flow.¹⁰⁷ This has forced NTT to turn to its mobile operation, DoCoMo, for profit. NTT DoCoMo is Japan's largest mobile operator.

German and UK regulators are using a version of Japan's contingent strategy to encourage broadband infrastructure firms to install next-generation access networks today, in order to catch up with the US, Canada, and Japan.

European Commission Directives. Members of the European Union (EU) are hypothetically bound by common European Commission (EC) telecom regulations such as the 2000 Local Loop Unbundling Directive and the 2002 Framework, Access and Interconnection, Universal Service,

Competition, and other directives.¹⁰⁸ EC telecom directives are not self-executing, however; each state must “transpose” the directive into national law, and each state’s NRA must then enforce it. This process always involves the injection of national policies:

Instead of the somehow deterministic vision of a uniform European information society, the national and local distinctiveness of the EU member states arises as an intervening factor that paints a diverse and differentiating picture of the information society across the EU: “there are many different configurations of the European Information Society. These configurations involve different industrial structures, different roles of users, and different approaches to policy in both the private and public sectors.”¹⁰⁹

As one might reasonably expect, the unbundling mandate produces a small but still substantial degree of competition, low prices, and a fairly rapid buildout in urban areas, but only low impact in rural ones. The unbundling mandate also discourages investment in advanced networks; several means such as “investment ladders,” “stepping-stones,” subsidies, and regulatory holidays are used in an attempt to escape from that effect, with varying degrees of effectiveness.¹¹⁰

The basic European approach is a fine prescription for the first stage of Basic Broadband, but it fails in the second stage.

The EC does more than simply issue edicts, however; it also acts as a convener for public/private partnerships and pressures member states to support projects of mutual interest such as its 5G Public-Private Partnership, launched in December with an indicative budget of €700M.¹¹¹

The EC approach to network regulation presupposes visions about technology development and even a theory of history. According to the EC vision, technology markets unfold because regulators make them develop; according to a contrary view, “accidents of history”

and ingenuity play a larger role. If the latter is the case, information gathering is a more important function for policymakers than regulation. Many nations, including some EU founders, firmly believe the accidents of history view is more accurate and beneficial.

United Kingdom. UK was the source of the EC unbundling and competition directives as a consequence of being the first to privatize its telephone network. It has modified the basic European approach by adopting Contingent Model measures similar to those used by Japan and Germany.

The basic European approach is a fine prescription for the first stage of Basic Broadband, but it fails in the second stage because the local loop must be reconfigured for Advanced Broadband; this requires both investment and coordination. As Plum Consulting explains, UK regulator Ofcom has changed course with respect to its LLU policy, shifting from an emphasis on bitstream competition (Wholesale Line Rate, WLR) to direct-to-wire (Metallic Path Facilities, MPF, and Shared Metallic Path Facilities, SMPF) competition to provide incentives for ISPs to deploy better DSL switches. As Brian Williamson and Sam Wood of Plum Consulting point out, Ofcom’s policies have been inconsistent.¹¹² Prior to 2004, Ofcom’s predecessor Oftel emphasized bitstream competition, but it shifted to LLU thereafter.

The Ofcom Strategic Review of Telecommunications concluded with a shift in strategy with greater focus on promoting competition at the deepest level of infrastructure possible (and unbundling i.e. MPF in particular) and recognising that there are trade-offs in promoting all kinds of competition in equal measure...¹¹³

In other words there may be benefits from taking a strategic view of market development rather than adopting a strictly neutral approach since (if the view is correct) the costs associated with trade-offs can then be minimised. There was deemed to be a need to steer the market in particular direction, this being towards

MPF-based competition in voice and what we now term Current Generation Access.¹¹⁴

Implementing Vectored DSL will require a shift back to bitstream. This is the sort of operational minutiae that preoccupies regulators under the LLU regime; there are several ways to unbundle the loop, so the question of which method is best often overshadows questions of the end user's maximum utility and value.

First-generation wire leasing is a barrier to the deployment of next-generation Vectored DSL, so it would have been better for Ofcom to move competitive ISPs Talk Talk and Sky away from MPF and toward WLR (bitstream). This does seem to be the current direction: "The shift to active products has been driven in the first instance by the different network technology and topology for fibre which makes unbundling relatively less attractive. Active products may also, in contrast to the situation with unbundling and ADSL, offer the best prospects for innovation and competition."¹¹⁵ While regulators may very well wish to be "technology neutral," the hands-on approach makes neutrality impractical.

The UK is stuck with DSL for the time being because BT's pretax free cash is too low to support FTTH deployment without massive subsidies. The first instance of such subsidies was a controversial £530 million rural broadband grant, followed by an additional (and also controversial) £1.2 billion grant to upgrade urban homes and businesses.¹¹⁶



Figure 71. People of Borwick Installing Their Network
Source: Motherboard
status.

The UK has managed to navigate a path through the complexities of local loop unbundling, limited facilities-based competition between cable and DSL, and massive subsidies to a well-performing and widely used wired infrastructure. The policy question is to what extent the UK has managed to encourage its formerly government-owned telecom, BT, to comply with regulators' wishes in its self-interest rather than in anticipation of subsidies. To the extent that BT is subsidy-driven, it effectively operates as an arm of the government, despite its putative private status.

The UK's predominantly urban/suburban population distribution has helped as well; some rural Britons have taken matters into their own hands rather than waiting for BT to wire their villages. In the parish of Borwick, near Lancaster, citizens have formed a community broadband project called B4RN (Broadband for the Rural North). The people of Borwick are digging their own trenches, laying fiber, and mastering the art of fiber splicing to construct a gigabit network (Figure 71).¹¹⁷ B4RN will be the fastest residential network in Europe.

BT has been granted a three-year regulatory holiday from Ofcom's price controls for its FTTH network; this is called "pricing flexibility" in the UK and is consistent with the Contingent Model's practiced use of limits on competitive access to advanced facilities.¹¹⁸ Contingent Model states allow easy access to legacy facilities, and much more restricted access to advanced ones. This becomes clearer when we examine Germany.

According to IHS, BT and the UK government have committed €5 billion to increase broadband capacity: "In 2013, the UK government committed to ensuring that 95 percent of UK homes

receive speeds of at least 24Mbit/s by 2017. Coupled with BT's investment in FTTC and FTTH broadband, intended to cover nearly 20 million homes by the end of 2014, over €5 billion is being spent on upgrading the UK's broadband infrastructure."¹¹⁹ BT's contribution will increase the firm's already-substantial debt, but interest in using the Internet and traffic loads in the UK are high compared to its EU partners.

Germany. Like the UK and the rest of the EU, Germany's regulators struggle with European Commission mandates to provide competition over a common wire plant while also trying to promote the investment-driven technology dynamics that enable broadband services to improve cost/performance ratios on a consistent basis. And like the UK (and unlike most of the EU), Germany has substantial cable broadband deployment: cable is available to approximately 55 percent of German people today.¹²⁰ Consequently, the history of broadband regulation in Germany is marked by a series of legal disputes between the EU and the German regulatory body, the Federal Network Agency (BNetzA).

In 2007, the German parliament granted Deutsche Telekom (DT) a three-year holiday from the line-sharing mandate for VDSL in a move intended to spur deployment of an advanced broadband technology. European Commission officials criticized the law and warned of legal action: "the granting of regulatory holidays to incumbent operators is an attempt to stifle competition in a crucial sector of the economy, and in violation of EU telecom rules in place since 2002."¹²¹ In 2009, the European Court of Justice agreed with the EC and struck down the German law.¹²²

But by that time, DT had reached leasing agreements with competitive Internet Service Providers Vodafone and 1x1 to open the VDSL network to competition on the condition that sharing went both ways, between DT's copper lines and competitors' fibers. Thus, DT is able to share competitors' fiber to lower its costs just as competitors are able to use DT's copper to lower their costs.

Both sides of these agreements follow the Contingent Model, in which access requires a minimum number of lines, as is the case for fiber access in Japan. This form of bilateral and contingent network access has become the norm in Germany and is active in the current push to provide greater Vectored DSL and FTTH deployment in that country.¹²³ It has also expanded into the mobile space, where access to fiber or fiberlike tower backhaul is a critical factor.¹²⁴ It has spread to the UK and other parts of Europe as well. The access that DT offers to its copper lines can also be obtained as either Data Link Layer (Layer 2 in the OSI model) frame streams or Network Layer (Layer 3) packet streams.

The push to raise speeds over DSL with VDSL, Vectored DSL, and FTTH in Germany is motivated in large part by the desire of DT to close the performance gap between DSL and cable. Since 2008, Germany has had the largest cable footprint in Europe (Figure 10).

Ironically, DT originally built the German cable TV system, but it was forced to sell it in 2003 to reduce debt and to finance its expansion into mobile.¹²⁵ The sale was complicated by the fragmentation of the cable network imposed by the German competition authority to deal with market concentration fears stemming from control of both cable and DSL by a common entity, albeit one in which government was a significant stakeholder:

A distinctive feature of the German cable infrastructure is its fragmentation into independently owned and operated cable franchises. The infrastructure is split into 4 different network levels. Level 1 comprises the production of TV- and Radio-Programming. Level 2 contains the transmission from production sites to reception-stations in the networks of level 3 operators. Level 3 is the actual backbone network of

coaxial cable that extends to the customer premises. Level 4 encompasses the last meters from the curb to the cable outlet in the customer's house/apartment.

DT formerly held 80 percent of level 3 and around 30 percent of level 4 infrastructure. Because the EU was considering legislation demanding the institutional separation of the cable and telecommunications business of former monopolies, DT in 1998 established a holding company for its cable activities. Of the 9 Cable Regions in the holding, DT sold three by the end of 2001. The cable infrastructure of the Bundesländer Nordrhein-Westfalen (NRW) and Baden-Württemberg (BW) were purchased to 55 percent and 45 percent by Callahan Associates International LLC, that operate under the company name "ish" in Germany. The cable infrastructure in Hessen now belongs to 65 percent to a consortium around Klesch & Company, a London-based private equity firm. The company name for the Klesch products is "iesy". The remaining shares continue in the possession of DT, however, the investors have the option to obtain the DT shares. The conflict of interest for DT concerning the success of the cable operators in voice-telephony and Internet access is obvious.¹²⁶

Germany has a national broadband plan addressing broadband performance goals, spectrum policy, uptake programs, and rural networks and the subsidy programs necessary to support them.

Arguably, the Contingent Model would not have emerged in Germany without BNetzA's willingness to disobey the EC and chart a course that made more sense for the German people than did the EC's "one size fits all" line-sharing mandate. The Contingent Model responds to local market conditions, in other words. When implemented in a bilateral fashion, contingent access becomes similar to the way that Internet operators negotiate interconnection agreements: on the basis of equal value.

Like the rest of Europe, and indeed, the rest of the developed world, Germany has a national broadband plan addressing broadband performance goals, spectrum policy, uptake programs, and rural networks and the subsidy programs necessary to support them.¹²⁷

The strategy, developed in 2009, targets 50 Mbps broadband availability to 75 percent of German homes by 2014 and emphasizes "synergies in construction projects." In terms of competitors, the strategy singles out France, Japan, and the US, and mentions no other nations.

Among the measures the strategy avows to pursue, one of great interest concerns the need to change European policy. Measure 11 ("Requirements related to incentives and investment stimulus in the EU regulatory framework") lays out two recommended policy changes:

At a European level, the Federal Government is seeking clarity within the EU telecommunications regulatory framework in order to achieve speedy and reliable modernization of networks.

- The additions sought to the framework directive should offset the investment risk by enabling innovative and intelligent cooperation mechanisms that will adequately spread the investment risk among the network operators and between the network operators and businesses requiring network access. The Federal Government will campaign at European level and among Member States for this type of incentive mechanism and the creation of an investment-friendly environment. Once these factors are in place, it will be possible to generate enormous sums that must be made available in the coming years for modernizing telecommunications networks. In the interests of competition, the Federal Government will monitor the incentive mechanisms to ensure that network access is available to all and that the principle of

non-discrimination is preserved. The regulations must not be allowed to distort market competition.

- The Federal Government is also advocating long-term planning certainty and consistent regulatory policy. Specifications made by the regulatory bodies must be guaranteed to be valid for more than three years and thus endure longer than the validity of a market analysis, if necessary. A stable regulatory climate is crucial for the necessary investment in next-generation networks.¹²⁸

This is a clear and sensible admission by a European government that the European local-loop unbundling policy retards network progress in nations with competitive broadband facilities unless it is modified by contingent and bilateral agreements. To the extent that Europe has been successful in deploying advanced broadband, it has departed from the standard EC model.

According to IHS, DT has committed substantial investment in coming years:

Deutsche Telekom made headlines when it committed in 2012 to a headline investment of €30 billion in high speed broadband technology in the years to 2015. A significant proportion of Deutsche Telekom's investment is actually committed to the US for LTE build-out, but €6 billion is still being devoted to next-generation broadband rollout in Germany. Deutsche Telekom intends to ensure that 65 percent of homes are covered by its fibre-to-the-cabinet (FTTC) network by 2016, with new 'vectoring' technology being deployed to raise transmission rates to 100Mbit/s.¹²⁹

Most of DT's increased investment will be spent in the US, however.

France. France has always had a curious relationship with the Internet. On the one hand, the fundamental ideas of Internet architecture were developed in France by the researchers who created the CYCLADES network in the early 1970s.¹³⁰ CYCLADES as a government-funded research project, and what the government funds it can also defund: CYCLADES was shut down in 1981 under pressure from France Telecom.

On the other hand, France's participation in and access to today's Internet are decidedly substandard, as the data on intensity of use, deployment and performance indicate. France stands out as the second largest market for DSL (92 percent of its wired broadband connections) and for the equal speed of its wired and mobile networks. Performance parity is more an indictment of the wired networks than an indication that its mobile ones are excellent.

France has devised two national broadband plans. Nicolas Sarkozy's government released the first plan in 2008, the *French Digital Plan 2012*. According to its architect, this plan would have enabled universal service and FTTH:

High speed access at 512 Kbps for less than 35 euros a month should become a universal service. An RFP could be issued in early 2009 to allocate this universal service to an operator. "Each French citizen, wherever he lives, will have a right to high speed access," Besson said. Elaborating further on infrastructure, Besson asserts that France is "now moving to ultra broadband networks and 4 million households will be connected through FTTH access by 2012, with €10 billion of investments for the next 10 years."¹³¹

While the universal service part has come to pass, FTTH continues to be very rare in France; the planned investment of €10 billion did not actually happen. François Hollande's government released its own plan in 2013, *France Très Haut Débit* (THD), echoing the Sarkozy plan's ambitious goals and doubling the promised funding to €20B.¹³²

While German regulators spar with the EC over unbundling regulations that appear calculated to dampen investment, France has been in conflict with Brussels for more than a decade on the

issues of its noncompliance with EC directives forbidding state aid to business.¹³³ In one instance, the EC penalized France for a bailout of France Telecom after it overextended itself in the Internet bubble, and in another, the EC opened an inquiry into excessive telephone termination fees French NRA ARCEP awarded to Iliad's Free.fr service.¹³⁴

Free.fr is a darling of American community broadband hawks who fail to appreciate the fact that ARCEP gave Free Mobile extraordinary concessions because it was desperate to create the appearance of dynamism in its stagnant mobile broadband market. For all practical purposes, Free Mobile was created by regulators and is supported by subsidies paid to Iliad by competitors, like a US rural telephone company. Objectively, its service is low quality; according to ARCEP, Iliad's Free Mobile service "got significantly worse results on a large number of indicators" and has the lowest overall quality of any mobile service in France.¹³⁵

It is not terribly surprising that France should develop national plans that rely so heavily on subsidies for very advanced technologies while its wired networks languish. France has

With the government calling the shots for the broadband industry and planners focused on lofty but impractical goals a generation or more beyond current needs, it is no wonder than France racks up low scores on Advanced Broadband.

developed an "innovation by permission culture" in which network operators are reluctant to act without direct financial support from the government; broadband operators were not allowed to offer VDSL in France until 2013, as the central government feared it would reduce the appetite for FTTH.¹³⁶

With the government calling the shots for the broadband industry and planners focused on lofty but impractical goals a generation or more beyond current needs, it is no wonder than France racks up low scores on Advanced Broadband. One sign of pragmatism does emerge from the Hollande plan, however: the government will spend

€70 million on satellite broadband targeted to rural areas.¹³⁷ It is not clear if those areas will actually be in France, but they will be served by French-made satellites: state aid, once again.

By relying on grandiose plans that it probably will never implement, France has created another policy paradigm, the Utility Model, in which the regulator seeks to be all-powerful by controlling the purse and micromanaging industrial dynamics.

IHS identifies massive potential investment in France:

In 2013, the French government set out plans to invest €20 billion of public and private funds in next-generation fixed and mobile broadband, aiming to cover half of the population by 2017, with the remaining homes covered within a further five years. "Crucially, the government's plans have stratified investment, asking ISPs to fund urban coverage, while providing a mixture of state and local government funding to ensure that semi-urban and rural areas are connected," [Richard] Broughton said.¹³⁸

History suggests a degree of skepticism should be applied to this announcement; the austerity measures that doomed prior plans still rule government decision making in France.¹³⁹

My assertion that France and Italy practice a different form of regulation than other EU nations is not entirely novel; Tsatsou and Jordana have made similar observations about the diversity of regulatory policies in the EU, noting, "Research identified a 'Southern European' interventionist approach to telecommunications regulation correlated with 'cultural affinities' of the countries in that region."¹⁴⁰

Italy. The policy story in Italy is virtually the same as in France: the nation is highly rural, was poorly connected prior to broadband, and is hemmed in by policies discouraging cable TV. In

1999, only 5 percent of Italian homes were passed by cable TV, but mobile phones were more common than in any other G7 nation, at 53 subscribers for every 100 people. As in Germany, cable regulations penalized size, so all cable networks were poorly capitalized.¹⁴¹ The Italian national broadband plan, *Italia Digitale*, has always placed great stock in FTTH; by 2008, there was still no cable modem service in Italy.

FTTH was never deployed outside a few cities and had not reached even 12 percent coverage by 2012. Italy had the highest 3G coverage among the European contingent of the G7 in 2009, 92 percent, but did not begin to move on LTE until 2012. It also did not move on VDSL until 2012, when its 4.5 urban percent coverage was dwarfed by 14.3 percent *rural* coverage and 47 percent urban coverage in the UK, but it did begin LTE and VDSL deployment ahead of France, as the analysis of broadband coverage shows in Figures 20, 22, and 23.

Italy's current target for broadband infrastructure simply follows the *Digital Agenda for Europe*: universal connectivity at a minimum of 30 Mbps, with at least 50 percent of households passed by Internet connections above 100 Mbps by 2020. Italy proposes to leverage private investment where possible and offers three other forms of subsidy: direct support, public/private partnerships, and incentives. There are certain common assumptions:

All three models predict the reuse of existing infrastructure of public and private property (ducts and existing infrastructure of multi-utility operators or local), which is defined as the acquisition of rights of use. In the case of re-use of existing infrastructure, please note that wholesale access obligations are not subject to restrictions, but must be guaranteed for at least 7 years.¹⁴²

Like France, Italy follows the Utility Model of grandiose but unrealized dreams.

The Italian plan appears light on specifics. This may be due to the relatively small number of documents available in English, but there is not much to found in the usual places. It is telling that Italy devises and articulates three forms of subsidy; it has no faith in free-market solutions at all.

Like France, Italy follows the Utility Model of grandiose but unrealized dreams. Where North America, Western Europe, and Japan write prose, Southern Europe writes poetry.

IHS reports that Italy has humble plans for government investment in wireline upgrades: "At the end of 2013, Telecom Italia ended speculation about its plans for next-gen broadband rollout by committing to significant investment in next-gen broadband – encompassing €1.8 billion in fixed access, and €0.9 billion in expanding its next-gen mobile network. The company aims to cover over half of the population with its 'ultrabroadband' by 2016."¹⁴³

This is a small but achievable goal for most nations of Italy's size.

Summary of Results

Now that we have analyzed the objective data and reviewed the policy background, we can construct a reasonable scorecard regarding the effectiveness of national policies. This necessarily involves weighting the mass of data, but as most of the raw data is presented in its original form, other researchers are free to construct their own ratings without digging too hard for objective information.

The first thing to do is to discard the seemingly obvious 1–7 ranking system for these seven nations. A simple ranking system creates artificial scarcity, and we do not want any of that in a broadband study. Analysis of the raw data suggests that most measurements show a clustering of nations into three groups in which differences within the group are less pronounced than those between groups.

On cable modem coverage, for example, the US and Canada each have more than 90 percent; Germany, the UK, and Japan are close to 50 percent, and France and Italy are below 30 percent. On FTTx coverage, Japan has 90 percent; the US, Italy, Canada, and France range from 23 to 6.5 percent, and Germany and the UK are below 3 percent. I will therefore score each category high, medium, and low and allow the number of nations in each group to be determined by the spreads within the data.

For all practical purposes, broadband at the basic level of either some form of DSL, cable, or satellite plus 3G is close enough to universal to no longer be an issue. Therefore, the scorecard focuses on Advanced Broadband and to a limited extent on Pervasive Broadband (FTTH and LTE Advanced). Specific speeds are implied by the diffusion measurements, so they are not repeated in the scorecard (Figure 72). The resulting ranking reflects regulatory models: Pioneer nations do best, Contingent states are next best, and Utility nations do the worst.

	Rural	NGA	LTE	Smart phone	>10M	Mobile >4M	Mobile Usage	Mobile Usage	Score
United States	1	2	1	1	2	2	1	2	1.50
Canada	1	2	1	2	2	1	1	2	1.50
Japan	3	1	2	2	1	1	2	1	1.63
United Kingdom	2	2	3	1	2	1	2	2	1.88
Germany	2	2	2	2	3	3	3	3	2.50
France	2	3	3	2	3	1	3	3	2.50
Italy	3	3	3	3	3	1	3	3	2.75

Figure 72. Broadband Quality Scorecard

Note: Lower numbers indicate a better score.

Sources: Author's calculations using various data cited in this study.

The column titles in Figure 72 represent the following:

Rural: Rural population per square kilometer of arable land (Figure 5).

NGA: NGA coverage in 2012 (Figure 17).

LTE: LTE coverage in 2012 (Figure 22).

Smartphone: Smartphone adoption (Figure 28).

>10M: Percent connections with Akamai ACS 10 Mbps or faster (Figure 38).

Mob >4M: Percent mobile connections with Akamai ACS 4 Mbps or faster (Figure 42).

Usage: Projected traffic usage level (Figure 61).

Mobile Usage: Projected mobile usage level (Figure 62).

AVG: Average of all indicators.

Conclusion

We can almost predict the standings in the G7 Broadband Scorecard on the basis of cable TV coverage in 1999; all nations except Italy retain their positions from that chart (Figure 7). This effect is not because of reliance on cable in today's broadband networks as much as a reflection of the role of competition.

Italy failed to deploy cable modem broadband, so it lost the competitive dynamic and slipped to last place, while Japan built a cable network and used it as the vehicle for its first broadband connections. (See Japan in "Other G7 Case Histories.") Robust competition between DSL and cable in the US and Canada obviated the need for those countries to impose local-loop unbundling, and satellite and terrestrial wireless services with high capacity offered a meaningful universal service solution.

Japan, the UK, and Germany responded to less robust but still substantial competition from cable by upgrading telecom networks to VDSL (UK and Germany, Figure 19) and to FTTH/B (Japan, Figure 11). LLU regulations in these countries follow the Contingent Model that discourages very small providers and allows incumbents and competitive carriers to negotiate mutually beneficial terms of interconnection.

Laggard nations France and Italy have formulated grand plans that can be implemented only on the backs of massive taxpayer subsidies that have not been forthcoming and may very well run afoul of EC prohibitions on state aid to telecoms and EC austerity policy if they are actually implemented.

Pursuing the number-one ranking in network connection speed is an unworthy goal.

The roles played by cable, satellite, and advanced mobile networks have less to do with the technical capabilities of these technologies (FTTH will always offer higher capacities than copper- or radio-based networks) than with their ability to energize competitive dynamics in the

broadband marketplace. While FTTH will always be faster, the capacity of the last-mile network is not the most important factor in the end user's experience of the web, web-server capacity is (see the "Browsing Speed" section). Consequently, pursuing the number-one ranking in network connection speed is an unworthy goal.

The best way to assess the success of a broadband strategy is on the basis of coverage by advanced technologies, usage of advanced technologies, useful performance, and an assessment of consumer price that takes provider cost, usage, and investment into account; the value assessment remains to be done.

On the holistic basis, the competitive Pioneer Model employed by the US and Canada outperforms the Contingent Model used in Japan, UK, and Germany, and the Contingent Model outperforms the single infrastructure Utility Model of France and Italy.

The menu of choices for policymakers is relatively simple: if we want a dynamic broadband marketplace in which citizens enjoy high-performance networks at reasonable prices, it is necessary for regulators to be humble enough to allow the competitive dynamic to unshackle human ingenuity. If we are content to follow the leader and move more slowly, we can adopt the Contingent Model with a micromanaging regulator. If we want stagnation, we can follow the Franco-Italian "almighty regulator" approach and bemoan our lack of progress.

The data point unambiguously to the proper path: if want a regulatory system that stimulates innovation, social benefits, and technology advances, we have to accept the Pioneer Model.

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Richard Bennett is a 30-year veteran of the network technology industry, where he made fundamental contributions to the standards for and design of Switched Ethernet, Wi-Fi, and Open Systems Interconnection. Bennett has been active in the policy debate around the broadband Internet since the emergence of the net neutrality issue. He was an invited witness at the FCC's first en banc hearing on net neutrality and has testified before Congress on Internet architecture and mobile broadband spectrum systems. An internationally known speaker and writer, he advises businesses and governments on network policy, appears on radio and television, and writes columns and op-eds for major publications such as the *New York Times* and *Wall Street Journal*. Bennett is presently a visiting fellow at the American Enterprise Institute's Center for Internet, Communications, and Technology Policy.

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